DEBRIS/ICE/TPS ASSESSMENT
AND
PHOTOGRAPHIC ANALYSIS
OF
SHUTTLE MISSION STS-32R

January 9, 1990

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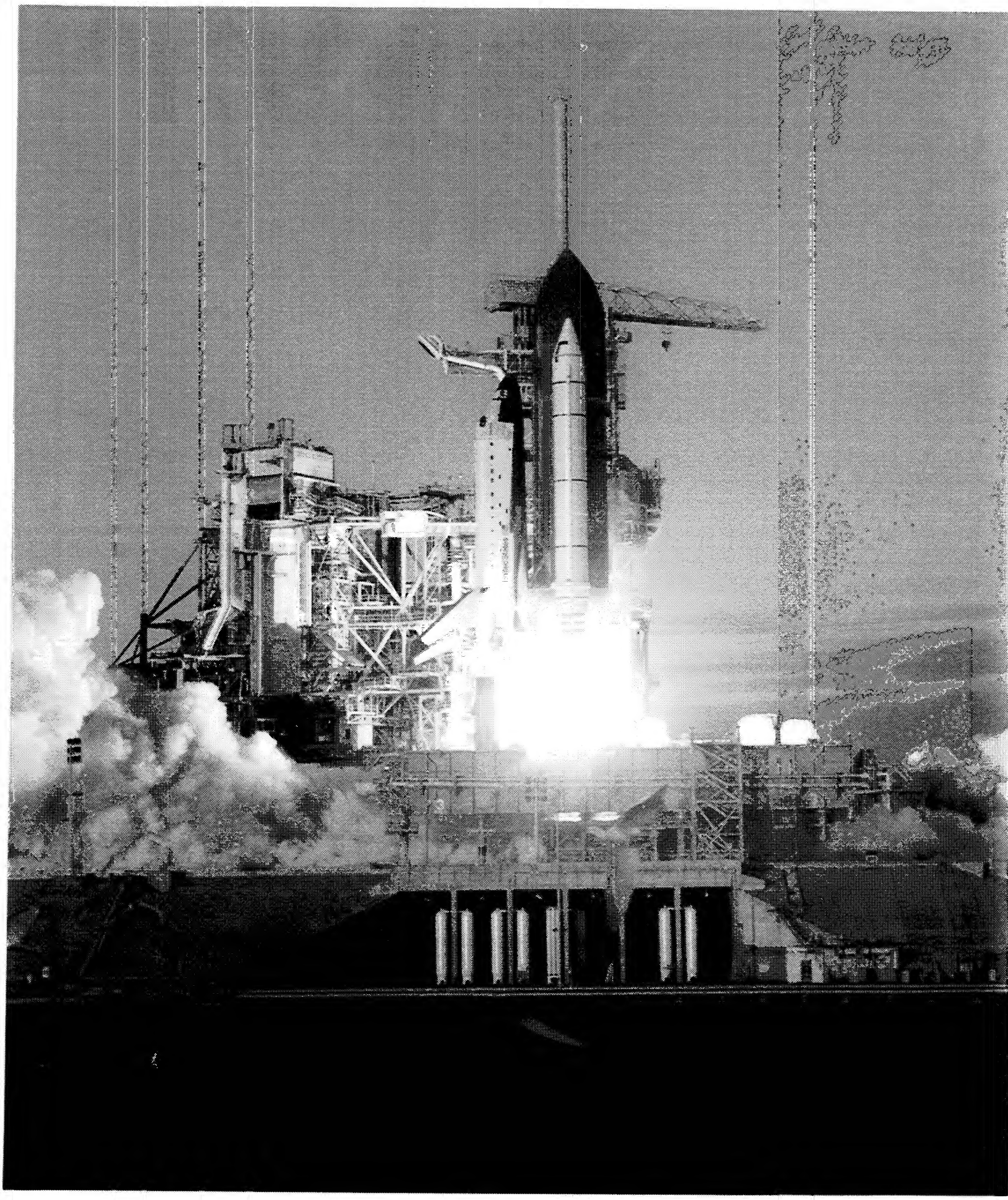
FORWARD

The Debris Team is continuing its effort to develop and implement measures to control damage from debris in the Shuttle operational environment and to make the control measures a part of routine processing and operations.



Launch of Shuttle Mission STS-32R on 1/9/90 at 7:35 a.m. EST

1.0 Summary

Debris and Photo Analysis Team activities for Mission STS-32R began with the pre-launch debris inspection of the launch pad and Shuttle vehicle on 7 January 1990. No major anomalies were observed on OV-102 Columbia, BI035, or ET-32. Although the ESP had been removed, a red GSE cover #RK395-40063-71 was still attached to SSME #1 at the 6 o'clock position between hatbands #8 and #9. The cover was removed prior to cryoload. No SRB anomalies or loose ablator/cork were observed with the exception of a 4"x2" piece of duct tape on the aft side of the -Y SRB upper strut fairing. A Problem Report on the tape was dispositioned with MRB approval to use-as-is. Minor facility discrepancies, which included loose MLP deck bolts and loose debris items in the holddown post haunch area, were corrected prior to cryo loading the vehicle.

One Orbiter tile anomaly, PR RWNG-2-09-3199, was documented on the right wing lower surface during the Ice Inspection. An orange GSE tile shim measuring 4 inches long by 1 inch wide by 0.030 inches thick protruded approximately 1 inch from black tiles at a position 4 rows aft of the wing leading edge RCC panel #14. Condensate, but no ice or frost, was present on all acreage areas of the External Tank. There were no unacceptable ET TPS anomalies. Seven Ice/Frost console anomalies were documented and found acceptable for launch per the LCC and NSTS-08303. One of these anomalies, documented on IPR 32RV-0229, involved the formation of three 4 inch and one 2 inch icicles on the end of the north GOX vent duct. The icicles formed because the hydro diverters had not been installed on the vent pipes during the pad modification period. Four icicles, the largest measuring 8 inches long by 1 inch in diameter, were removed by the Ice Team using the specially designed retrieval net. A Problem Report was initiated to install the hydro diverters prior to the next launch attempt. The hydrogen umbilical leak sensor detected no significant hydrogen during the cryo load and was removed by the Ice Inspection Team during the T-3 hour hold.

The launch was scrubbed due to RTLS weather violations. A post drain inspection was performed five hours after the scrub decision. No TPS damage, such as divots or cracks, were present on the tank acreage. A small amount of ice/frost formed on the leak check port closeout on the ET aft dome siphon manhole. In addition to the ice/frost, a small amount of vapor was visible emanating from this area. This condition was acceptable per NSTS-08303. There was no damage to the Orbiter or SRB TPS.

The vehicle was again cryo loaded after a 24 hour scrub/turnaround. No new Orbiter or SRB anomalies were detected during the Ice Inspection. Condensate was present on all acreage areas of the External Tank. Minor frost had formed in several areas on both the LO2 and LH2 intertank flanges. One TPS anomaly occurred on the aft dome apex. A SLA vent closeout

2 inches in diameter was protruding 3/8 inch. PR TS-0063 was taken and dispositioned with MRB approval to fly-as-is. Hard ice was present in the LO2 feedline bellows and support brackets. Light accumulations of frost on the LO2 ET/Orbiter umbilical were typical. The LH2 ET/Orbiter umbilical exhibited greater than average ice/frost accumulation. There were no unusual vapors emanating from the umbilicals or any evidence of leakage. The GOX vent duct hydro diverters from Pad B were installed on Pad A prior to cryoload and prevented icicle formation. Twelve Ice/Frost console anomalies were documented and found acceptable for launch per the LCC and NSTS-08303. At launch, the ET ice condition was well within the data base for ice formation.

A post launch debris inspection of Pad 39A was performed after launch. A large piece of white tile screed (4"x3-5/8"x1/2" maximum thickness) was found west of the FSS in the box car area. The screed was an unrestricted 364 repair on tile V070-197004-069, which is located in the forward, outboard corner on the RH outboard elevon upper surface. Although 3 Orbiter Q-felt plugs were recovered, no significant flight hardware or TPS material was found. Launch damage to the holddown posts was minimal. South holddown post shim material was intact, but had debonded significantly from the shoe sidewall. The shim on Holddown post #2 shoe was completely debonded and could be lifted. No signs indicative of stud hang-up were visible. No fragments from HDP debris containers were found. The GH2 vent line had latched properly. Overall there was very little damage to the launch pad.

A total of 118 film and video items were analyzed as part of the post launch data review. No major vehicle damage or lost flight hardware was observedx that would have affected the success of the mission. However, the white tile screed repair found at the pad after launch was visible falling from the RH outboard elevon just before the vehicle completed the roll maneuver. Frangible links between the Debris Containment System (DCS) plungers and the holddown post studs were omitted for this flight in an attempt to eliminate stud hang-ups. However, this change caused a considerable amount of debris to fall from the vehicle during liftoff. A total of seventeen frangible nut and NSI cartridge fragments were observed falling from HDP #3, #5, #7, and #8. The orange GSE tile shim discovered by the Ice Team during the scrub ice inspection fell from the RH wing at liftoff without causing any visible tile damage. Numerous pieces of debris from the vehicle were visible during ascent. Most have been identified as ice/frost particles from the ET/Orbiter umbilicals, RCS paper covers, and instafoam particles from the SRB aft skirts. More than 100 chunks of SRB propellant slag were visible in the SRB plumes prior to and just after separation from the External Tank.

One 35mm and two 16mm cameras in the ET/ORB umbilicals recorded SRB and ET separation. These cameras revealed several divots in the ET acreage. Two divots measuring 12-14 inches in diameter were apparent on the intertank acreage between the bipod and just above the intertank-to-LH2 tank flange. A third divot 14 inches in diameter was centered between the bipod ramps and extended into the intertank-to-LH2 tank flange. The largest divot, measuring 28 inches wide, surrounded the forward part of the LH bipod ramp. Stringers were visible in the divots indicating a depth greater than the isochem line. Two divots, one of which was a repair, were also noted missing from the LH2 tank acreage in the spray abort areas.

The Solid Rocket Boosters were inspected at Hanger AF after retrieval. Both forward skirts and frustums exhibited a total of 29 debonds. The LH frustum lost a 2-inch divot of MSA-2 TPS near the 275 ring. All field joint closeouts were undamaged. The LH aft segment stiffener/stiffener factory joint EPDM moisture seal was debonded on the leading edge at 230 degrees (3.5" long by 1" deep) and 280 degrees (3" long by 1.25" deep). Portions of the phenolic plates on both the RH and LH +Z RSS antennas were missing. The PDL pour on the aft side of the RH IEA was missing and the bolt head underneath was sooted. The RH +Y IEA end cover aft outboard corner was broken off and a bolt head on the adjacent cover was broken off. Another cover bolt was missing near the aft side of the RH upper strut. HDP #1, #2, #3, #7, and #8 plungers were not seated and the remaining plungers were seated on offset spherical washers. The percentage of frangible nut/NSI debris (not including frangible nut halves) retained by the DCS's was measured to be:

HDP #1	45%	HDP #5	32%
HDP #2	53%	HDP #6	70%
HDP #3	35%	HDP #7	91%
HDP #4	68%	HDP #8	59%

The quantity of DCS debris lost during this launch is considered by the Debris Team to be unacceptable and a potential unnecessary hazard to the vehicle.

A post landing inspection of OV-102 was performed on Runway 22 and in the Mate/Demate Device. The Orbiter TPS sustained a total of 120 hits, of which 15 had a major dimension of one inch or greater. The Orbiter lower surface had a total of 111 hits, of which 13 had a major dimension of one inch or greater. Based on these numbers and comparison to statistics from previous missions of similar configuration, the number of hits on the lower surface is average. Also, based on the severity of damage as indicated by surface area and depth, this flight is better than average. Although the Orbiter was found to be in excellent condition, it was discovered during pyro removal that the RH Y-Y stop-bolt from the forward attach point EO-1 bolt's centering mechanism was compressed and bent. The EO-1 ordnance device spring housings were also found to have been scratched

due to contact with both the LH and RH bulkhead pyro connector backshells. The damaged assembly was removed for analysis to determine the cause for these anomalies.

A total of 20 Post Launch Anomalies were observed during this mission assessment.

2.0 KSC ICE/FROST/DEBRIS TEAM ACTIVITIES

Team Composition: NASA KSC, NASA MSFC, NASA JSC, LSOC SPC, RI - DOWNEY, MMMSS - MAF, USBI - BPC, MTI - UTAH

Team Activities:

1) Prelaunch Pad Debris Inspection

Objective:	Identify and evaluate potential debris material/sources. Baseline debris and debris sources existing from previous launches.
Areas:	MLP deck, ORB and SRB flame exhaust holes, FSS, Shuttle vehicle external surfaces
Time:	L - 1 day
Requirements:	OMRSD S00U00.030 - An engineering debris inspection team shall inspect the shuttle and launch pad to identify/resolve potential debris sources. The prelaunch vehicle/pad configuration shall be documented/photographed.
Documents:	OMI S6444
Report:	Generate PR's and recommend corrective actions to pad managers.

2) Launch Countdown Firing Room 2

Objective:	Evaluate ice/frost accumulation on the shuttle vehicle and/or any observed debris utilizing OTV cameras.
Areas:	MLP deck, FSS, Shuttle vehicle external surfaces
Time:	T - 6 hours to Launch + 1 hour or propellant drainback
Requirements:	OMRSD S00FB0.005 - Monitor and video tape record ET TPS surfaces during loading through prepressurization.
Documents:	OMI S0007, OMI S6444
Report:	OIS call to NTD, Launch Director, and Shuttle managers. Generate IPR's.

3) Ice/Frost TPS and Debris Inspection

Objective:	Evaluate any ice formation as potential debris material. Identify and evaluate any ORB, ET, or SRB TPS anomaly which may be a debris source or safety of flight concern. Identify and evaluate any other possible facility or vehicle anomaly.
Areas:	MLP deck, FSS, Shuttle vehicle external surfaces
Time:	T - 3 hours (during 2 hour BIH)
Requirements:	OMRSD S00U00.020 - An engineering debris inspection team shall inspect the shuttle for ice/frost, TPS, and debris anomalies after cryo propellant loading. Evaluate, document, and photograph all anomalies. During shuttle walkdown inspect orbiter aft engine compartment (externally) for water condensation and/or ice formation in or between aft compartment tiles An IR scan is required during the shuttle inspection to verify ET surface temperatures. During shuttle walkdown, inspect ET TPS areas which cannot be observed by the OTV system.
Documents:	OMI S0007, OMI S6444
Report:	Briefing to NTD, Launch Director, Shuttle management; generate IPR's.

4) Post Launch Pad Debris Inspection

Objectives:	Locate and identify debris that could have damaged the Shuttle vehicle during launch.
Areas:	MLP deck, flame exhaust holes and trenches, FSS, pad surfaces and slopes, extension of trenches to perimeter fence, walkdown of the beach from Playalinda to Complex 40, aerial overview of inaccessible areas.
Time:	Launch + 3 hours (after pad safing, before washdown)
Requirements:	OMRSD S00U00.010 - An engineering debris inspection team shall perform a post launch pad/area inspection to identify any lost flight or ground systems hardware

and resultant debris sources. The post launch pad/area configuration shall be documented/photographed.

Documents:	OMI S0007, OMI S6444
Report:	Initial report to LTD and verbal briefing to Level II at L+8 hours; generate PR's.

5) Launch Data Review

Objective:	Detailed review of high speed films video tapes, and photographs from pad cameras, range trackers, aircraft and vehicle onboard cameras to determine possible launch damage to the flight vehicle. Identify debris and debris sources.
Time:	Launch + 1 day to Launch + 6 days
Requirements:	OMRSD S00U00.011 - An engineering film review and analysis shall be performed on all engineering launch film as soon as possible to identify any debris damage to the space shuttle vehicle. Identify flight vehicle or ground system damage that could affect orbiter flight operations or future SSV launches.
Documents:	OMI S6444
Report:	Daily reports to Level II Mission Management Team starting on L+1 day through landing; generate PR's.

6) SRB Post Flight/Retrieval Inspection

Objective:	Evaluate potential SRB debris sources. Data will be correlated with observed Orbiter post landing TPS damage.
Areas:	SRB external surfaces (Hangar AF, CCAFS)
Time:	Launch + 24 hours (after on-dock, before hydrolasing)
Requirements:	OMRSD S00U00.013 - An engineering debris damage inspection team shall perform a post retrieval inspection of the SRB's to identify any damage caused by launch debris. Any anomalies must be documented/photographed and coordinated with the results of the post launch shuttle/pad area debris inspection.

Documents:	OMI B8001
Report:	Daily reports to Level II Mission Management Team. Preliminary report to SRB Disassembly Evaluation Team. Generate PR's.

7) Orbiter Post Landing Debris Damage Assessment

Objective:	Identify and evaluate areas of damage to Orbiter TPS due to debris and correlate, if possible, source and time of occurrence. Additionally, runways are inspected for debris and sources of debris.
Areas:	Orbiter TPS surfaces, runways
Time:	After vehicle safing on runway, before towing
Requirements:	OMRSD S00U00.040 - An engineering debris inspection team shall perform a prelanding runway inspection to identify, document, and collect debris that could result in orbiter damage. Runway debris and any facility anomalies which cannot be removed/corrected by the Team shall be documented and photographed; the proper management authority shall be notified and corrective actions taken.
Requirements:	OMRSD S00U00.050 - An engineering debris inspection team shall perform a post landing runway inspection to identify and resolve potential debris sources that may have caused vehicle damage but were not present or were not identified during the pre-launch runway inspection. Obtain photographic documentation of any debris, debris sources, or flight hardware that may have been lost on landing.
Requirements:	OMRSD S00U00.060 - An engineering debris inspection team shall map, document, and photograph debris-related Orbiter TPS damage and debris sources.
Requirements:	OMRSD S00U00.012 - An engineering debris damage inspection team shall perform a post landing inspection of the orbiter vehicle to identify any damage caused by launch debris. Any anomalies must be documented/

photographed and coordinated with the results of the post launch shuttle/pad area debris inspection.

Requirements: OMRSD V09AJ0.095 - An engineering debris inspection team shall perform temperature measurements of RCC Nose Cap and RCC RH Wing Leading Edge Panels 9 and 17.

Documents: OMI S0026, OMI S0027, OMI S0028

Report: Briefing to NASA Convoy Commander and generate PR's. Preliminary report to Level II on the day of landing followed by a preliminary update the next day.

8) Level II report

Objective: Compile and correlate data from all inspections and analyses. Results of the debris assessment, along with recommendations for corrective actions, are presented directly to Level II via SIR and PRCB. Paper copy of complete report follows in 3 to 4 weeks. (Ref NASA Technical Memorandum series).

3.0 PRE-TEST BRIEFING

The Ice/Frost/Debris Team briefing for launch activities was conducted on 7 January 1990 at 0800 hours with the following key personnel present:

C. Stevenson	NASA - KSC	Chief, ET Mechanical Systems Lead, Ice/Debris Assess Team
G. Katnik	NASA - KSC	ET Mech/TPS, Ice/Debris Assessment, STI
S. Higginbotham	NASA - KSC	STI, Debris Assessment
B. Speece	NASA - KSC	ET Processing, Ice Assess
B. Bowen	NASA - KSC	ET Processing, "SURFICE"
J. Rivera	NASA - KSC	ET Processing, Debris Assess
A. Oliu	NASA - KSC	"SURFICE", Debris Assess
M. Bassignani	NASA - KSC	ET Processing, Ice Assess
B. Davis	NASA - KSC	STI, Debris Assessment
K. Tenbusch	NASA - KSC	"SURFICE", Debris Assess
J. Hoffman	LSOC - SPC	ET Processing, Ice Assess
M. Young	LSOC - SPC	ET Processing, Ice Assess
M. Jaime	LSOC - SPC	ET Processing, Ice Assess
J. Blue	LSOC - SPC	ET Processing, Ice Assess
F. Huneidi	NASA - MSFC	TPS & Ice Assessment
D. Andrews	NASA - MSFC	Debris Assessment
Z. Byrns	NASA - JSC	Level II Integration
C. Gray	MMC - MAF	ET TPS & Materials Design
S. Copsey	MMC - MAF	ET TPS Testing/Certif
P. Harner	MMC - KSC	ET Processing, LSS
J. McClymonds	RI - Downey	Debris Assess, LVL II Integ
T. Thorson	RI - LSS	Vehicle Integration
H. Novak	USBI - PSE	SRB Processing
H. Huppi	MTI - Utah	SRM Plant Representative
K. Parsons	MTI - LSS	SRM Processing

These personnel participated in various team activities, assisted in the collection and evaluation of data, and wrote reports contained in this document.

3.1 PRE-LAUNCH SSV/PAD DEBRIS INSPECTION

The pre-launch debris inspection of the pad and Shuttle vehicle was conducted on 7 January 1990 from 0930 - 1200 hours. The detailed walkdown of Launch Pad 39A and MLP-3 also included the primary flight elements OV-102 Columbia (9th flight), ET-32 (LWT-25), and BI035. Documentary photographs were taken of facility anomalies, potential sources of vehicle damaging debris, and new vehicle configurations.

There were no major vehicle anomalies. Although the ESP had been removed, a red GSE cover #RK395-40063-71 was still attached to SSME #1 at the 6 o'clock position between hatbands #8 and #9. The cover was removed prior to cryoload. The RH SRB BSM covers had been painted, the LH side was not. A piece of duct tape adhered to the aft side of the -Y upper strut fairing.

Due to the continued concern over potential hydrogen leakage from the ET/ORB LH2 umbilical interface area during the cryoload/launch of STS-28R, a temporary hydrogen detector was installed at the ET/ORB LH2 umbilical until a permanent sensor can be designed and installed. The temporary detector consists of two tygon tubes that run from the LH2 umbilical area to the hazardous gas detection equipment located on the FSS. The tubes were attached to the vehicle by three velcro strap assemblies. A length of parachute cord attached to these assemblies enable the entire apparatus to be quickly removed from the vehicle without causing TPS damage. The hydrogen sensor is intended to remain in place during cryo loading and be removed by the Ice Inspection Team during the T-3 hour hold.

A recurring problem is loose MLP deck bolts. This inspection revealed loose deck bolts on the deck panel southwest of the vehicle, between the SRB exhaust holes adjacent to the sound suppression water pipe, and in the deck plate east of the LO2 TSM. A nut and washers were missing from a U-bolt support on the south side of the LO2 TSM.

Other discrepancies included a missing electrical connector box covers on the MLP west side adjacent to the Portable Purge Unit connection point and on the MLP east side near the east stairs. A grounding strap was loose with only one end attached near the south side of the LH2 TSM adjacent to the SSME exhaust hole. An entire pipe spout, along with its cap and tether wire retaining screw, west of the LH SRB was loose. The north MLP access door had been closed on a rope and was not sealed.

Trash and debris was visible in several areas. Red tape was attached to the southwest side of holddown post #1. Debris and a plastic cap were visible in the haunch area of HDP #2. Masking and silver duct tape near HDP #5 was loose. Instafoam had been oversprayed on HDP #6.

Structural features to prevent icicle formation on the Pad B GOX vent ducts had not been incorporated on Pad A. Hydro diverters, which prevent water and condensate from running to the duct ends and freezing, had not been installed. This had been approved by PR - MRB.

Cleanup of the MLP deck and pad surface was almost complete at the time of the inspection. The facility discrepancies were worked real-time or transferred to the pad leader for resolution prior to vehicle tanking.

Red GSE cover on SSME #1 was removed prior to cryoload

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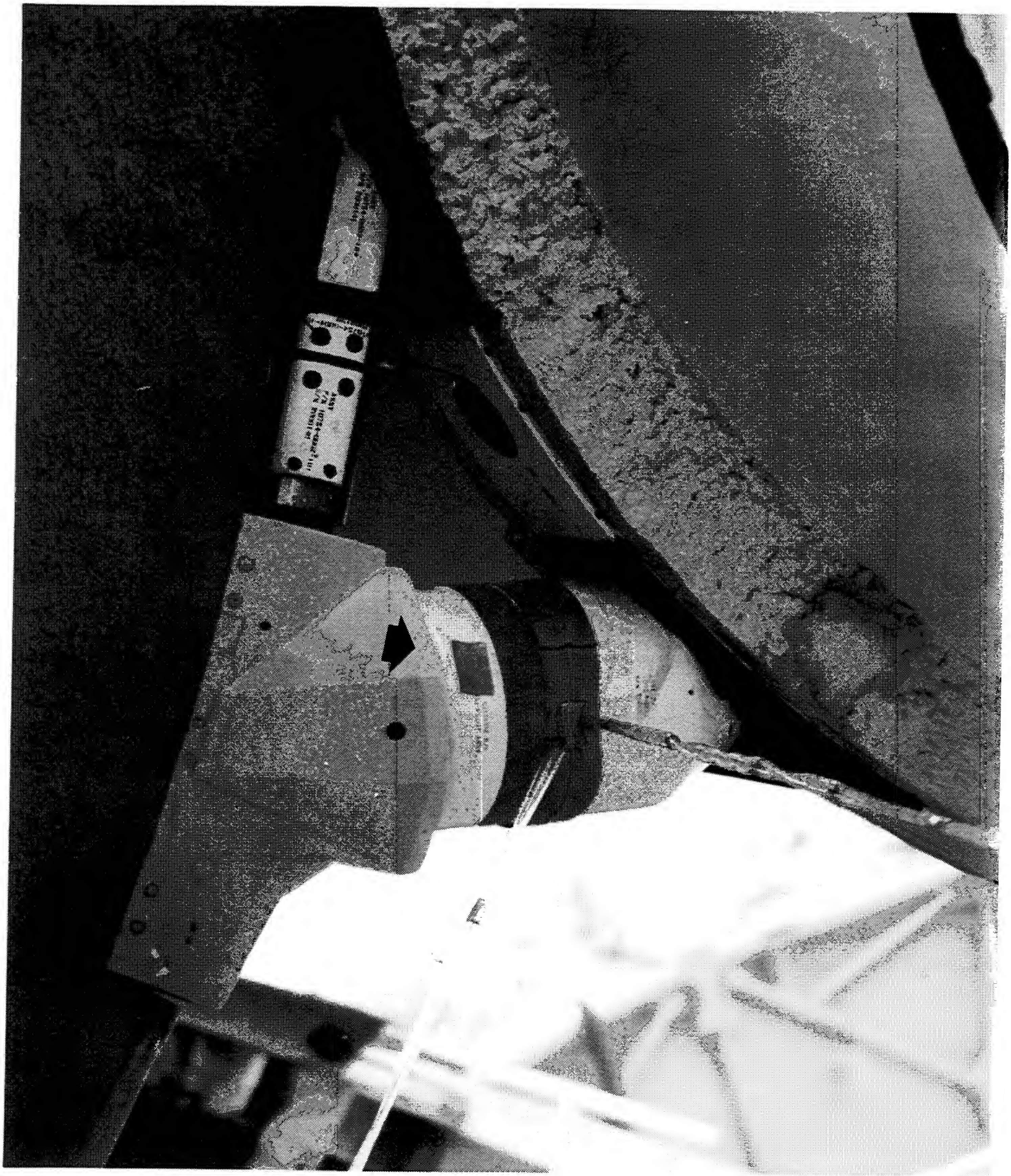
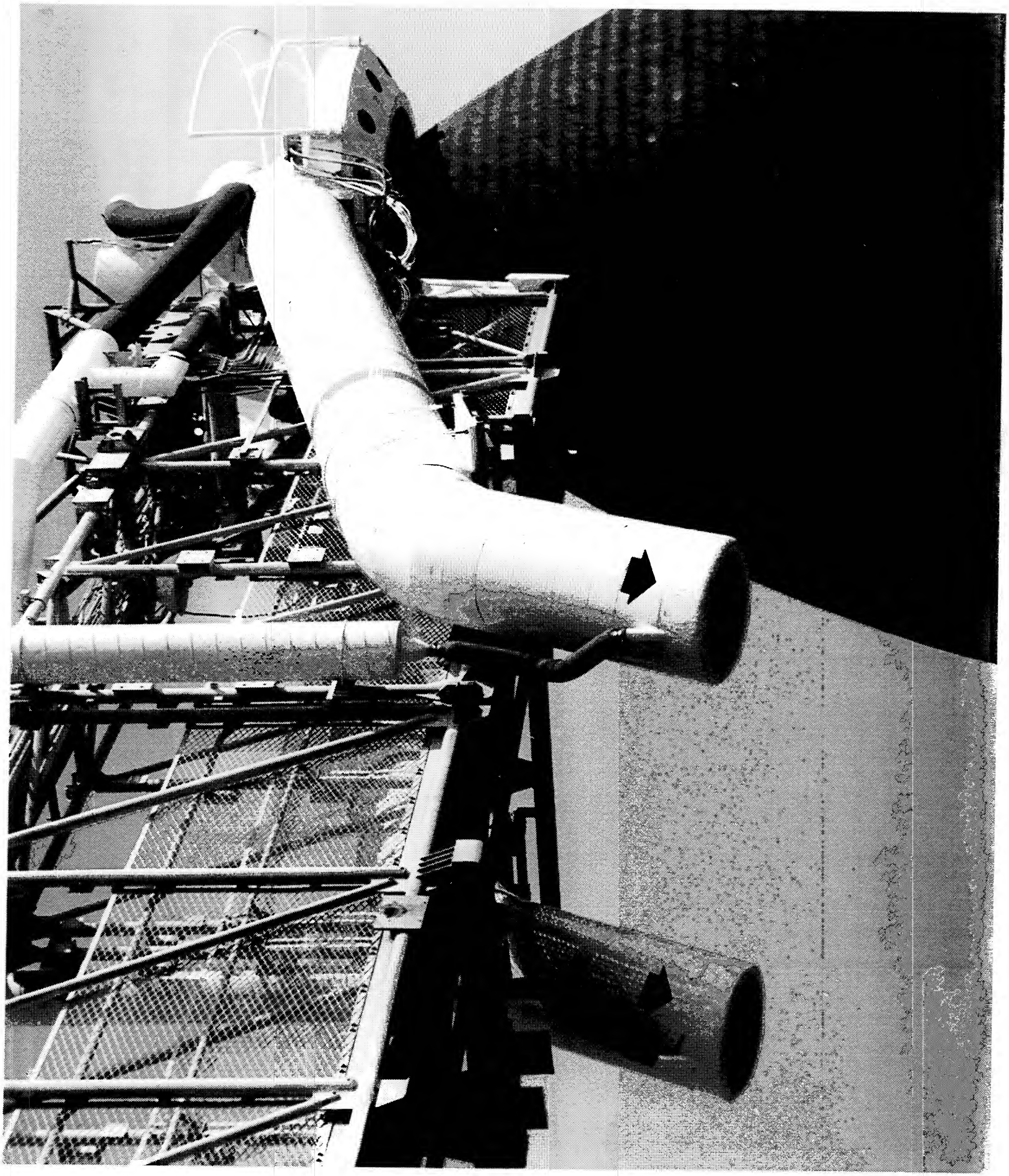
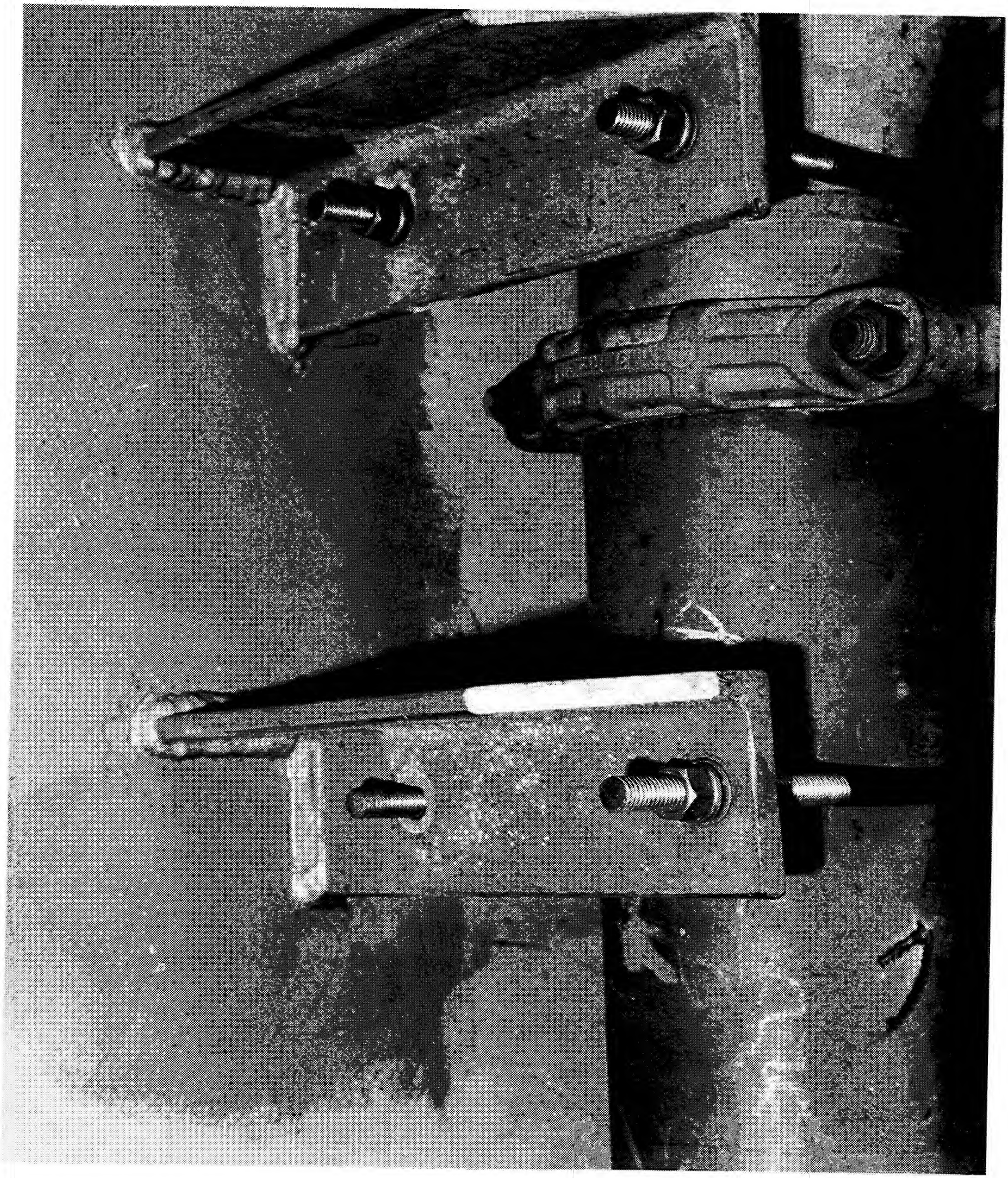
COLOR PHOTOGRAPH



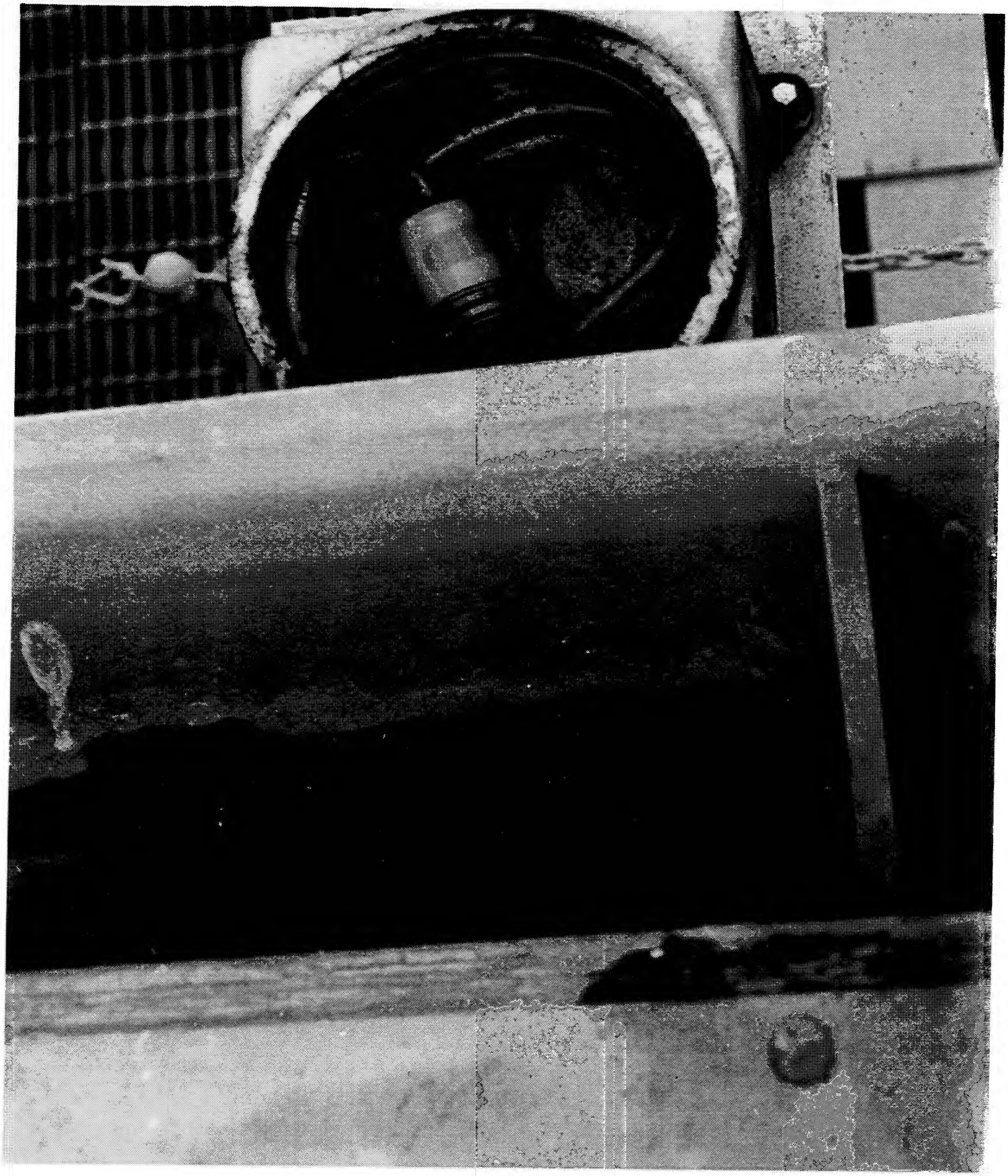
4-inch piece of duct tape of the aft side of the LH upper strut fairing remained for flight per MRB approval



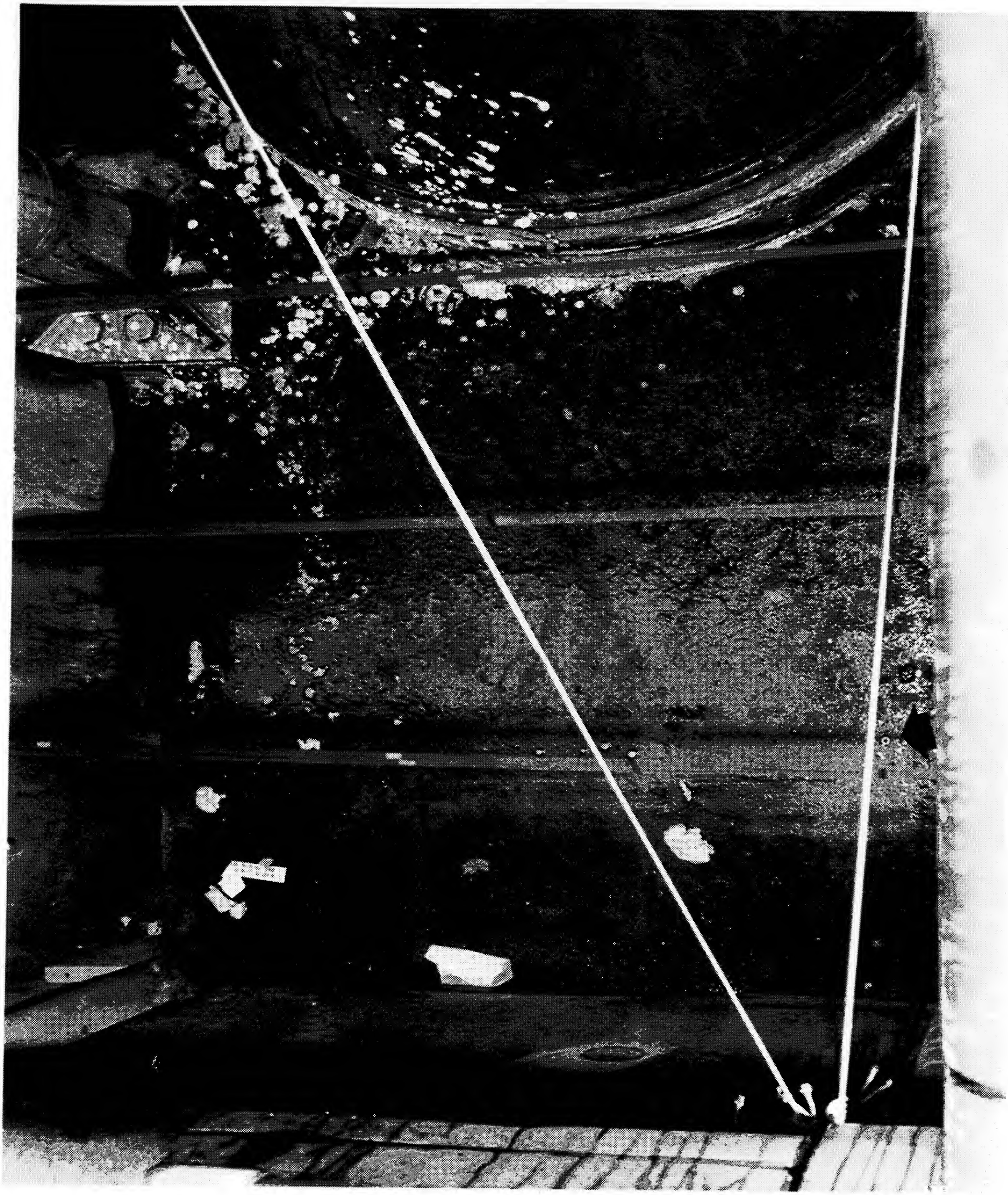
Absence of hydro diverters, which had not been installed on the GOX vent ducts, eventually caused the formation of icicles.



A U-bolt on the sound suppression pipe near the SSME exhaust hole was missing a nut and washer



A cover was missing from the electrical box on the MLP NW side



Metal nut and foam overspray/trimmings in the HDP #6 haunch

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4.0 SCRUB

The launch countdown for STS-32R was scrubbed at 0905 EST on 8 January 1990 due to RTLS weather LCC violations.

4.1 ICE/FROST INSPECTION

The Ice/Frost Inspection of the cryoloaded vehicle was performed on 8 January 1990 from 0210 to 0510 hours during the three hour built-in-hold at T-3 hours in the countdown. There were no violations of NSTS-08303 or the Launch Commit Criteria. Ambient weather conditions at the time of the inspection were:

Temperature:	68.1 F
Relative Humidity:	99.5 %
Wind Speed:	10.9 Knots
Wind Direction:	180 Degrees

The portable STI infrared scanner was utilized to obtain surface temperature measurements for an overall thermal assessment of the vehicle, as shown in Figure 1 and 2.

4.2 ORBITER OBSERVATIONS

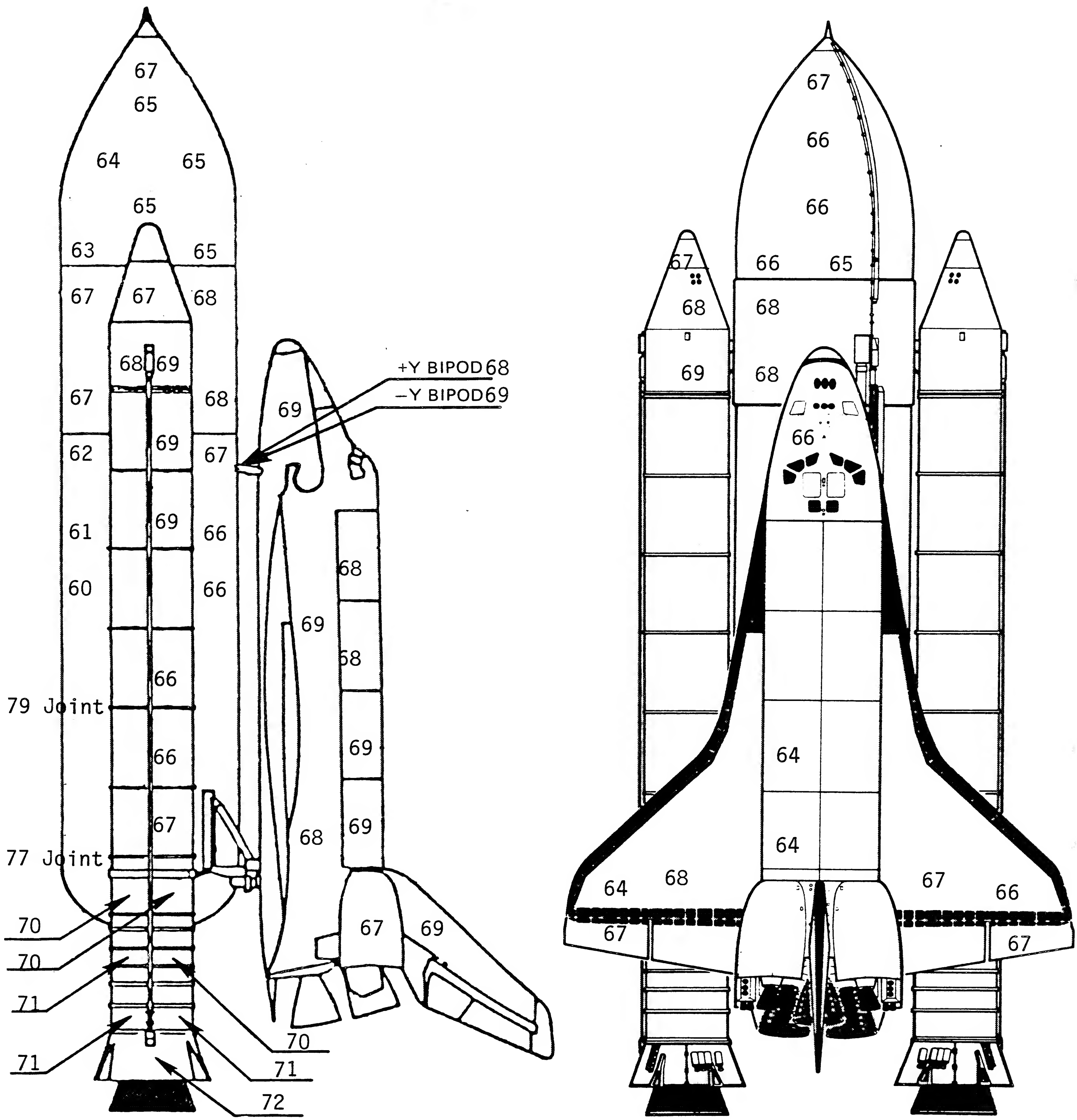
One Orbiter tile anomaly, PR RWNG-2-09-3199, was documented on the right wing lower surface. An orange GSE tile shim measuring 4 inches long by 1 inch wide by 0.030 inches thick protruded approximately 1 inch from the black tiles at a position 4 rows aft of the wing leading edge RCC panel #14. The average Orbiter surface temperature was recorded as 64-70 degrees F. The average surface temperatures of the SSME engine mounted heat shields were measured at 66 degrees F for SSME #1, 66 degrees F for SSME #2, and 67 degrees F for SSME #3. SSME #1 had a small amount of ice at the nozzle to heatshield interface 6 o'clock position. Condensate, but no ice or frost, was present on all three heat shields. A prevailing wind from the south displaced SSME oxygen overboard vapors into the engine bell nozzle.

4.3 SRB OBSERVATIONS

No SRB anomalies or loose ablator/cork were observed with the exception of a 4-inch long by 2-inch wide piece of duct tape on the aft side of the -Y SRB upper strut fairing. A Problem Report was dispositioned by SRB Engineering with MRB approval to use-as-is. The STI portable infrared scanner recorded RH and LH SRB case surface temperatures between 66 to 69 degrees F. Temperatures in the area of the SRB field joint heaters averaged 79 degrees F. The predicted Propellant Mean Bulk Temperature (PMBT) supplied by MTI was 64 degrees F.

FIGURE 1. **INFRA RED SCANNER SSV SUMMARY DATA**

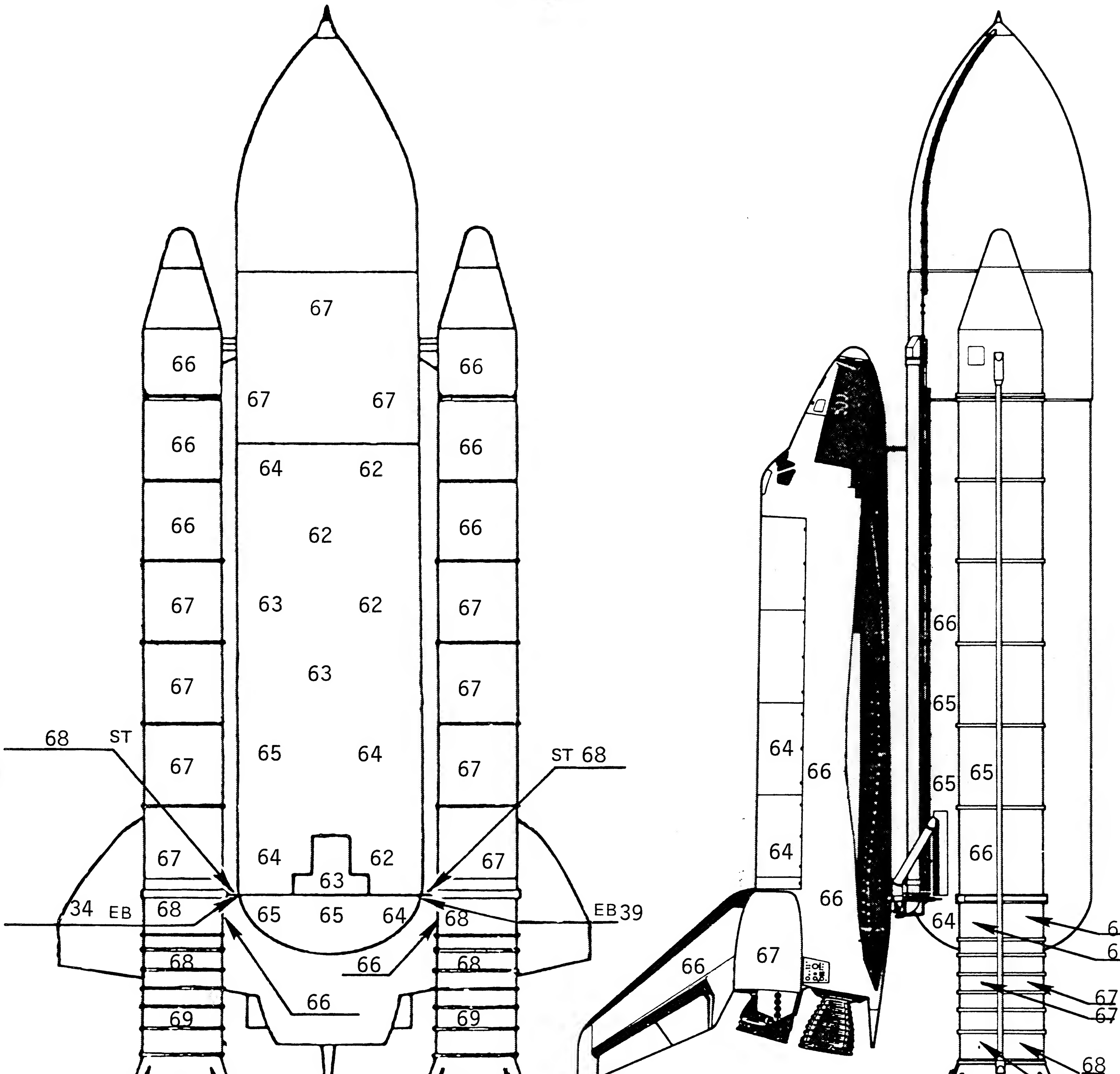
TIME: 0210-0510
DATE: 1/8/90
VEH. STS- 32R



EGG/V−343D

FIGURE 2. **INFRA RED SCANNER SSV SUMMARY DATA**

TIME: 0210-0510
DATE: 1/8/90
VEH. STS- 32R



SSME 1: 66 avg, 46 I/F
SSME 2: 66 avg, 43 I/F
SSME 3: 67 avg, 47 I/F

4.4 EXTERNAL TANK OBSERVATIONS

The ice/frost prediction computer program was run from 2300 to 0845 hours and the results tabulated in Figures 3, 4, and 5. The program predicted condensate with no ice accumulation on all TPS acreage surfaces.

Acreage condensate, but no ice or frost, was present on the LO2 tank, Intertank (run on), and LH2 tank. The IR scanner measured an average surface temperature of 65 degrees F on the LO2 tank, 68 degrees F on the Intertank, and 62 degrees F on the upper and lower LH2 tank.

A greater-than-average amount of condensate trickled down the LH2 tank and ran off the aft dome. There was no acreage ice or frost.

Ice/Frost covered the lower EB fittings outboard to the strut pin hole with condensate on the rest of the fitting. The struts were dry and were not covered by ice.

The TPS in the +Y longeron to LH2 tank interface had cracked and ice/frost had formed. This condition is acceptable per NSTS-08303.

Normal amounts of ice were present in all LO2 feedline bellows and in the LO2 feedline support brackets. These conditions are acceptable per NSTS-08303.

There was very little ice in the LH2 feedline bellows. A normal amount of ice had formed in the LH2 recirculation line bellows.

The LH2 ET/ORB umbilical exhibited less ice but slightly more than normal accumulations of frost. The LO2 ET/ORB umbilical exhibited typical (light) ice/frost accumulations. The largest frost accumulation was located on the aft side of the LO2 umbilical. Frost fingers had formed on the purge vents and normal venting was occurring. There were no unusual vapors emanating from the umbilicals nor any evidence of leakage.

Minor frost had formed around the GUCP, but there was no sign of leakage.

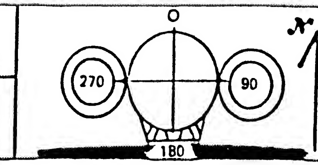
The tumble valve cover was properly installed and intact.

The ET/ORB hydrogen detection sensor tygon tubing was removed with no damage to the vehicle.

The summary of Ice/Frost Team observation anomalies consists of 8 OTV recorded items:

Anomaly 001 recorded three 4-inch and one 2-inch long icicles on the end of the north GOX vent duct and was documented on IPR 32RV-0229. One 4-inch icicle fell at GMT 09:11. All remaining

STS - 32R	TEST: S0007 RTLS Weather Scrub				DATE: 1/7/90	T-0 TIME: DATE: 1/8/90
ORBITER OV-102	ET 32	SRB B1035	MLP 3	PAD 39A	LO_2 CHILLDOWN TIME: 2231, FAST FILL TIME: 2342, SLOW FILL TIME: 2329, REPLENISH TIME: 0142	LH_2 CHILLDOWN TIME: 2252, FAST FILL TIME: 2326, SLOW FILL TIME: 2302, REPLENISH TIME: 0122



LOCAL TIME	CONDITIONS: TEMP. °F	REL. HUM. %	DEW PT °F	WIND VEL. KNTS	WIND DIR DEG	LO_2 TANK STA 370 TO 540: REGION	LOCAL VEL KNTS	SOFI TEMP °F	COND RATE IN/HR	ICE RATE IN/HR	LO_2 TANK STA 550 TO 852: REGION	LOCAL VEL KNTS	SOFI TEMP °F	COND RATE IN/HR	ICE RATE IN/HR	LH_2 TANK STA 1130 TO 1380: REGION	LOCAL VEL KNTS	SOFI TEMP °F	COND RATE IN/HR	ICE RATE IN/HR	LH_2 TANK STA 1380 TO 2058: REGION	LOCAL VEL KNTS	SOFI TEMP °F	COND RATE IN/HR	ICE RATE IN/HR
2300	70.9	90	67.93	13	203	II	7.67	64.36	.0029	.2645	II	7.67	61.40	.0050	.2323	II	4.16	55.88	.0049	.1188	II	17.68	64.90	.0052	.5227
2315	70.2	92	67.85	12	198	II	7.08	63.74	.0031	.2432	II	7.08	60.55	.0051	.2124	II	5.04	57.25	.0052	.1437	II	4.56	56.35	.0051	.1289
2330	69.9	93	67.85	14	196	II	8.26	64.19	.0032	.2779	II	8.26	61.39	.0033	.2455	II	5.88	58.40	.0054	.1686	II	5.32	57.58	.0053	.1513
2345	69.5	94	67.86	11	193	II	7.67	63.81	.0033	.2589	II	7.67	60.82	.0053	.2268	II	5.46	57.66	.0054	.1547	II	4.94	56.80	.0053	.1388
2400	69.2	95	67.75	15	190	II	8.85	64.09	.0034	.2919	II	8.85	61.44	.0055	.2593	II	6.30	58.56	.0056	.1781	II	5.70	57.77	.0055	.1601
0015	69.1	96	67.95	12	185	II	7.08	63.38	.0034	.2398	II	7.08	60.18	.0054	.2080	II	5.04	56.81	.0054	.1408	II	4.56	55.90	.0053	.1262
0030	68.5	97	67.64	10	186	II	5.90	62.17	.0034	.1999	II	5.90	58.42	.0053	.1689	II	4.20	54.60	.0052	.1121	II	3.80	53.58	.0051	.0999
0045	68.3	98	67.73	10	188	II	5.90	62.15	.0035	.1998	II	5.90	58.39	.0053	.1687	II	4.20	54.56	.0053	.1119	II	3.80	53.55	.0051	.0998
0100	69.1	98	68.53	11	191	II	6.49	63.44	.0036	.2257	II	6.49	60.01	.0055	.1941	II	4.62	56.45	.0055	.1308	II	4.18	55.49	.0053	.1170
0115	69.2	98	68.63	11	196	II	6.49	63.55	.0036	.2268	II	6.49	60.13	.0055	.1951	II	4.62	56.57	.0055	.1315	II	4.18	55.62	.0054	.1177
0130	69.1	98	60.53	13	194	II	7.67	64.10	.0037	.2621	II	7.67	61.12	.0057	.2299	II	5.46	57.93	.0057	.1568	II	4.94	57.06	.0056	.1407
0145	68.8	98	68.63	11	188	II	5.90	63.15	.0035	.2083	II	5.90	59.44	.0054	.1770	II	4.20	55.66	.0054	.1184	II	3.80	54.66	.0052	.1058
0200	68.7	99	68.52	12	183	II	6.49	63.31	.0037	.2246	II	6.49	59.88	.0056	.1930	II	4.62	56.30	.0055	.1298	II	4.18	55.34	.0054	.1161
0215	68.3	99	68.02	11	177	II	6.49	62.76	.0036	.2195	II	6.49	59.30	.0055	.1880	II	4.62	55.69	.0055	.1260	II	4.18	54.73	.0053	.1126
0230	68.5	99	66.22	11	185	II	6.49	62.96	.0036	.2215	II	6.49	59.53	.0036	.1900	II	4.62	55.94	.0055	.1275	II	4.18	54.97	.0054	.1140

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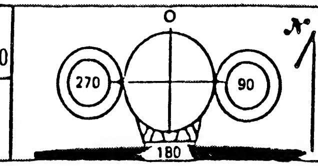
FIGURE 3. Ice/Frost Computer Predictions

STS – 32R	TEST: S0007 Launch - RTLS Weather Scrub	DATE: 1/8/90	T-0 TIME: DATE: 1/8/90
ORBITER OV– 102	ET 32 · SRB B1035 · MLP 3 · PAD A	LO_2 CHILLDOWN TIME: 2231 FAST FILL TIME: 2342 SLOW FILL TIME: 2329 REPLENISH TIME: 0142	LH_2 CHILLDOWN TIME: 2252 FAST FILL TIME: 2326 SLOW FILL TIME: 2302 REPLENISH TIME: 0122



LOCAL TIME	CONDITIONS					LO_2 TANK STA 370 TO 540					LO_2 TANK STA 550 TO 852					LH_2 TANK STA 1130 TO 1380					LH_2 TANK STA 1380 TO 2058				
	TEMP. °F	REL HUM. %	DEW PT °F	WIND VEL KNTS	WIND DIR DEG	REGION	LOCAL VEL KNTS	SOFI TEMP °F	COND RATE IN/HR	ICE RATE IN/HR	REGION	LOCAL VEL KNTS	SOFI TEMP °F	COND RATE IN/HR	ICE RATE IN/HR	REGION	LOCAL VEL KNTS	SOFI TEMP °F	COND RATE IN/HR	ICE RATE IN/HR	REGION	LOCAL VEL KNTS	SOFI TEMP °F	COND RATE IN/HR	ICE RATE IN/HR
0245	68.4	99	68.12	10	179	II	5.90	62.46	.0036	.2025	II	5.90	58.72	.0054	.1713	II	4.20	54.90	.0054	.1713	II	3.80	53.88	.0052	.1016
0300	68.1	99	67.82	11	175	II	6.49	62.54	.0036	.2175	II	6.49	59.07	.0055	.1861	II	4.62	55.45	.0055	.1861	II	4.62	55.45	.0055	.1245
0315	67.7	100	67.70	10	173	II	5.90	61.88	.0036	.1976	II	5.90	58.11	.0055	.1660	II	4.20	54.25	.0054	.1101	II	3.80	53.22	.0052	.0890
0330	67.4	100	67.40	12	184	II	7.08	62.32	.0037	.2296	II	7.08	59.07	.0056	.1981	II	5.04	55.62	.0056	.1329	II	4.56	54.68	.0054	.1187
0345	67.9	100	67.90	10	182	II	5.90	62.10	.0036	.1995	II	5.90	58.34	.0055	.1684	II	4.20	54.49	.0054	.1116	II	3.80	53.47	.0052	.0994
0400	68.3	100	68.30	11	184	II	6.49	62.96	.0037	.2214	II	6.49	59.51	.0056	.1898	II	4.62	55.90	.0056	.1273	II	4.18	54.93	.0054	.1138
0415	67.8	100	67.80	12	188	II	7.08	62.77	.0038	.2339	II	7.08	59.53	.0057	.2023	II	5.04	56.10	.0056	.1361	II	4.56	55.17	.0055	.1217
0430	68.4	99	68.12	11	183	II	6.49	62.87	.0036	.2205	II	6.49	59.41	.0055	.1890	II	4.62	55.81	.0055	.1268	II	4.18	54.85	.0053	.1133
0445	68.5	99	68.22	11	194	II	6.49	62.98	.0036	.2215	II	6.49	59.53	.0056	.1900	II	4.62	55.94	.0055	.1275	II	4.18	54.97	.0054	.1140
0500	68.8	99	68.52	12	186	II	7.08	63.67	.0037	.2428	II	7.08	60.47	.0057	.2109	II	5.04	57.09	.0057	.1428	II	4.56	56.18	.0055	.1280
0515	68.4	99	68.12	13	182	II	7.67	63.54	.0037	.2562	II	7.67	60.53	.0057	.2241	II	5.46	57.31	.0057	.1523	II	4.94	56.43	.0056	.1365
0530	68.2	99	67.92	12	172	II	7.08	63.01	.0037	.2362	II	7.08	59.78	.0056	.2045	II	5.04	56.37	.0056	.1379	II	4.56	55.45	.0055	.1234
0545	68.0	99	67.72	12	177	II	7.08	62.79	.0037	.2341	II	7.08	59.55	.0056	.2024	II	5.04	56.13	.0056	.1363	II	4.56	55.21	.0054	.1219
0600	68.2	99	67.92	11	181	II	6.49	62.65	.0036	.2185	II	6.49	59.18	.0055	.1871	II	4.62	55.57	.0055	.1252	II	4.18	54.60	.0053	.1119
0615	67.7	99	67.42	11	183	II	6.49	62.10	.0036	.2135	II	6.49	58.60	.0055	.1822	II	4.62	54.97	.0054	.1215	II	4.18	53.99	.0053	.1083

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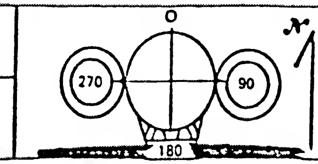
FIGURE 4. Ice/Frost Computer Predictions

STS - 32R	TEST: S0007 Launch - RTLS Weather Scrub	DATE: 1/8/90	T-0 TIME: DATE: 1/8/90



ORBITER	ET	SRB	MLP	PAD	LO_2	LH_2
OV- 102	32	B1035	3	A	CHILLDOWN TIME: 2231 FAST FILL TIME: 2342 SLOW FILL TIME: 2329 REPLENISH TIME: 0142	CHILLDOWN TIME: 2252 FAST FILL TIME: 2326 SLOW FILL TIME: 2302 REPLENISH TIME: 0122

LOCAL TIME	CONDITIONS					LO_2 TANK STA 370 TO 540					LO_2 TANK STA 550 TO 852					LH_2 TANK STA 1130 TO 1380					LH_2 TANK STA 1380 TO 2058				
	TEMP. °F	REL HUM. %	DEW PT °F	WIND VEL KNTS	WIND DIR DEG	REGION	LOCAL VEL KNTS	SOFI TEMP °F	COND RATE IN/HR	ICE RATE IN/HR	REGION	LOCAL VEL KNTS	SOFI TEMP °F	COND RATE IN/HR	ICE RATE IN/HR	REGION	LOCAL VEL KNTS	SOFI TEMP °F	COND RATE IN/HR	ICE RATE IN/HR	REGION	LOCAL VEL KNTS	SOFI TEMP °F	COND RATE IN/HR	ICE RATE IN/HR
0630	68.1	99	67.82	11	183	II	6.49	62.54	.0036	-.2175	II	6.49	59.07	.0055	-.1861	II	4.62	55.45	.0055	-.1245	II	4.18	54.48	.0053	-.1112
0645	67.8	99	67.52	13	184	II	7.67	62.88	.0037	-.2493	II	7.67	59.85	.0057	-.2175	II	5.46	56.60	.0057	-.1471	II	4.94	55.71	.0055	-.1317
0700	68.1	99	67.82	14	185	II	8.26	63.48	.0038	-.2703	II	8.26	60.65	.0058	-.2380	II	5.88	57.58	.0058	-.1622	II	5.32	56.73	.0057	-.1455
0715	68.4	99	68.12	12	183	II	7.08	63.23	.0037	-.2384	II	7.08	60.01	.0056	-.2066	II	5.04	56.61	.0056	-.1396	II	4.56	55.69	.0055	-.1249
0730	68.6	98	68.03	11	178	II	6.49	62.89	.0036	-.2206	II	6.49	59.93	.0055	-.1892	II	4.62	55.85	.0054	-.1269	II	4.18	54.88	.0053	-.1135
0745	68.3	99	65.02	12	182	II	7.08	63.12	.0037	-.2373	II	7.08	59.90	.0056	-.2056	II	5.04	56.49	.0056	-.1387	II	4.56	55.57	.0055	-.1242
0800	68.6	98	68.03	11	183	II	6.49	62.89	.0036	-.2206	II	4.62	59.43	.0055	-.1892	II	4.62	55.85	.0054	-.1269	II	4.18	54.88	.0053	-.1135
0815	69.3	98	68.73	11	181	II	6.49	63.66	.0036	-.2278	II	6.49	60.24	.0055	-.1961	II	4.62	56.69	.0055	-.1323	II	4.18	55.74	.0054	-.1185
0830	69.9	97	69.04	13	189	II	7.67	64.76	.0036	-.2692	II	7.67	61.81	.0056	-.2368	II	5.46	58.67	.0057	-.1621	II	4.91	57.81	.0056	-.1457
0845	69.9	97	69.04	10	196	II	5.90	63.72	.0035	-.2132	II	5.90	60.04	.0054	-.1818	II	4.20	56.30	.0054	-.1222	II	3.80	55.31	.0052	-.1093
AVG	68.7	98		12	S			63.15					59.80					56.26					55.59		

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FIGURE 5. Ice/Frost Computer Predictions

icicles were removed by the Ice Team at GMT 10:00. By GMT 10:11 two icicles had formed again on the end of the duct. Icicles fell at GMT 12:33 with one reforming after 10 minutes.

Anomaly 002 documented an ice/frost formation and some venting in the +Y thrust strut to LH2 tank interface area. The condition was acceptable per NSTS-08303.

Ice/frost formations on the purge vents and around the ET/ORB umbilicals were documented on Anomaly 003. These formations have been observed on previous tanking test, flight readiness firings, and launch cryoloadings and were acceptable per NSTS-08303.

Anomaly 004 recorded ice/frost accumulations in the LO2 feedline bellows and support brackets at all stations. This condition has occurred on previous launches and was acceptable per NSTS-08303.

Anomaly 005 documented unequal flow of vapors from the GOX vent ducts as an information-only item. This event has occurred on previous launches.

A frost formation at the +Y/aft corner of the aft hard point closeout was recorded on Anomaly 006. It was acceptable per NSTS-08303.

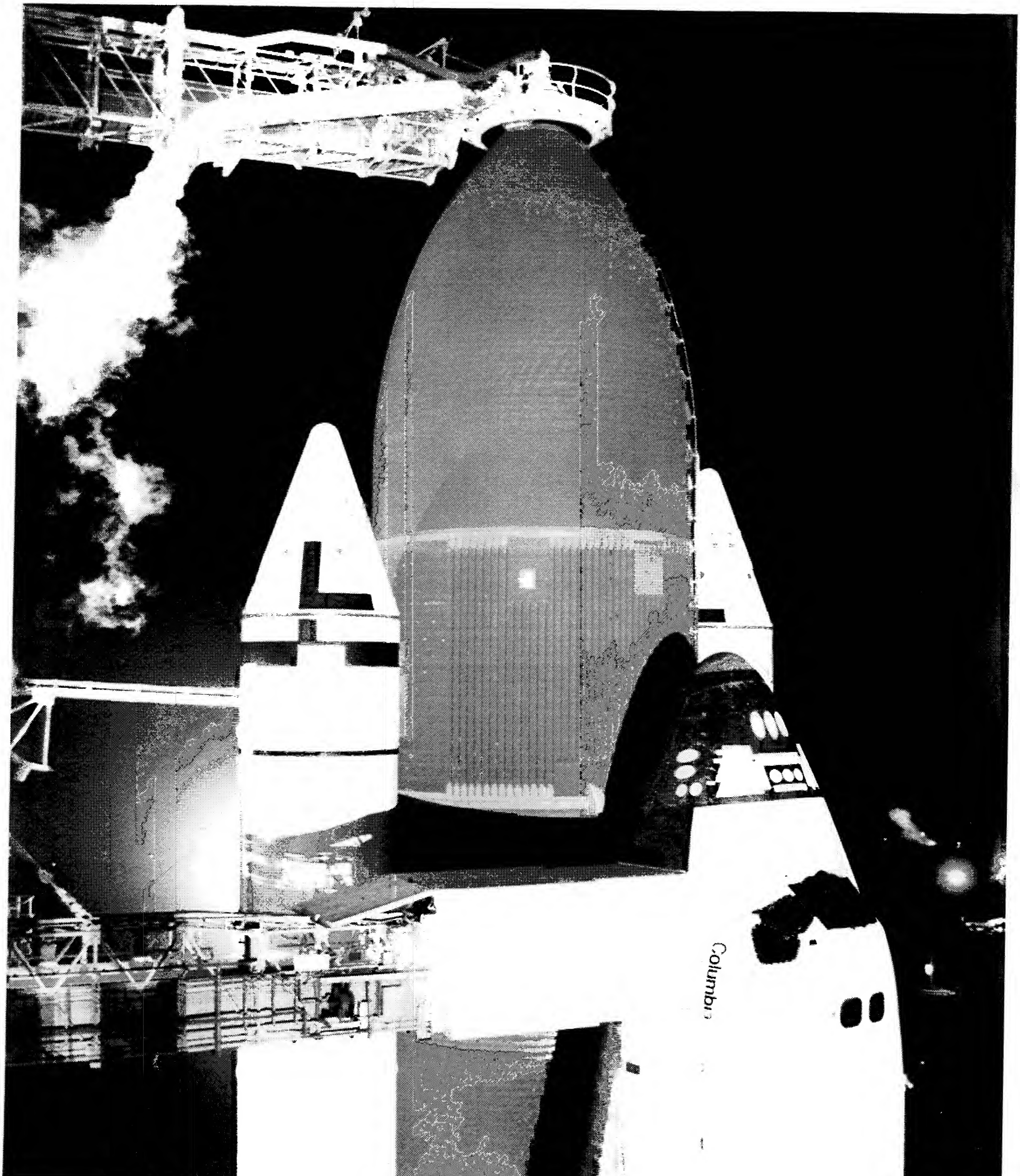
Anomaly 007 recorded three small areas of missing paint in the -Y GOX footprint topcoat. The areas were located outside of the GOX vent seal in the seated position and there was no evidence of chafing to the seal or the TPS surface. In addition, there appeared to be no depth to the areas of missing paint. This condition was acceptable to the Ice/Debris Team.

Anomaly 008 documented an orange GSE tile shim protruding from the black tiles up to 1 inch over a 4 inch span on the lower RH wing approximately 4 rows inboard/aft of RCC panel 14. This anomaly was documented on PR RWNG-2-09-3199 and was accepted for flight by MRB.

4.5 FACILITY OBSERVATIONS

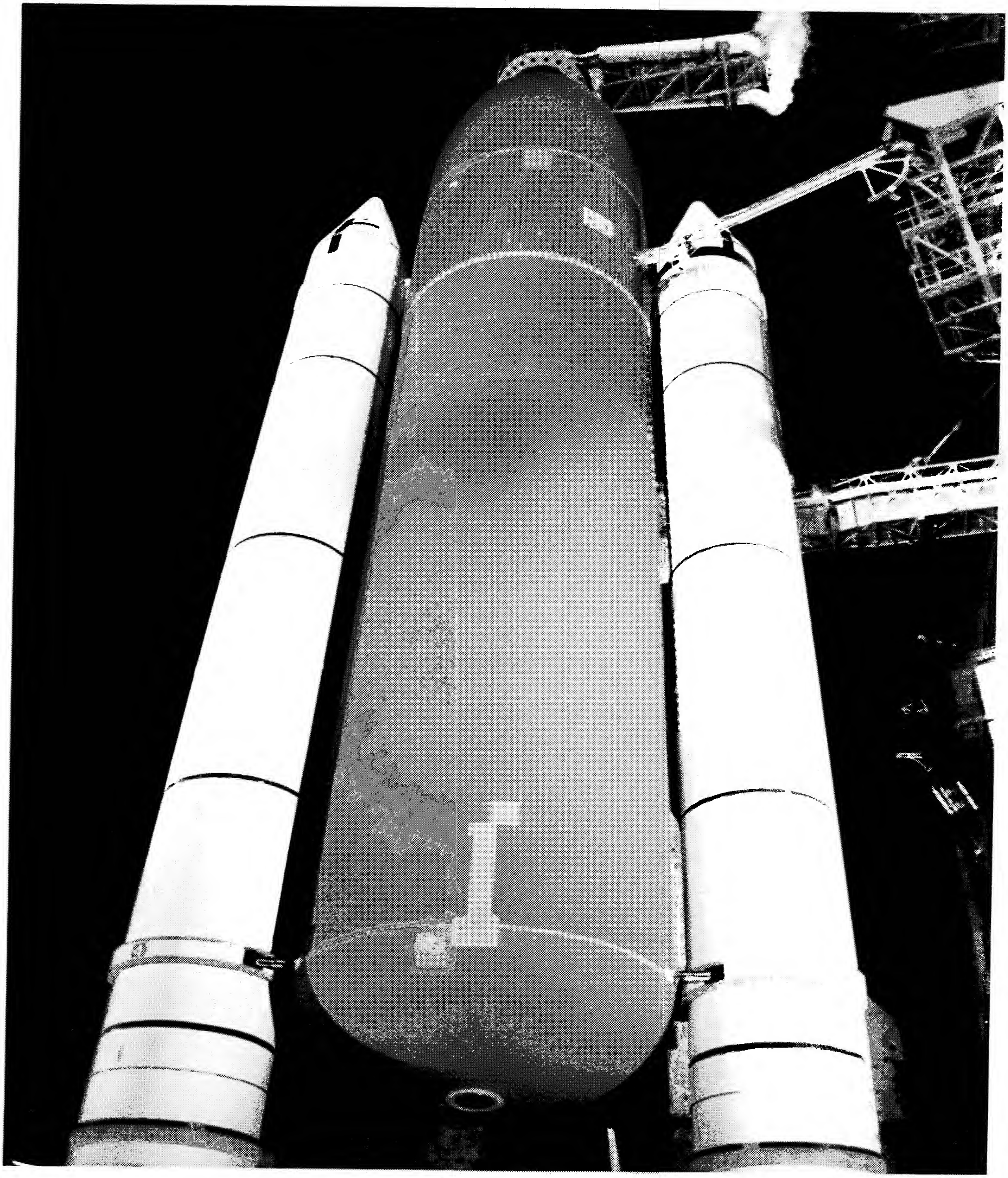
All debris concerns previously identified had been resolved prior to cryoloading and no new items were noted during the walkdown. No leaks were observed on either the LO2 or LH2 ORB T-0 umbilicals, though small amounts of ice had formed. Some condensate dripped from the LO2 TSM umbilical. There was no apparent leakage anywhere on the GH2 vent line or at the ET interface. The modification to the GH2 vent line prevented ice from forming but some ice/frost, which was expected, had accumulated on the GUCP legs. Visual and infrared observations of the GOX seals confirmed no leakage.

Icicles had begun to form on the ends of the GOX vent ducts during the ice/frost inspection. The icicles formed because the water diverters had not been installed on the vent pipes during the pad modification period. Four icicles, the largest measuring 8 inches long by 1 inch in diameter, were removed by the Ice Team using the specially designed retrieval net. A PR was initiated to install the water diverters prior to the next launch attempt.



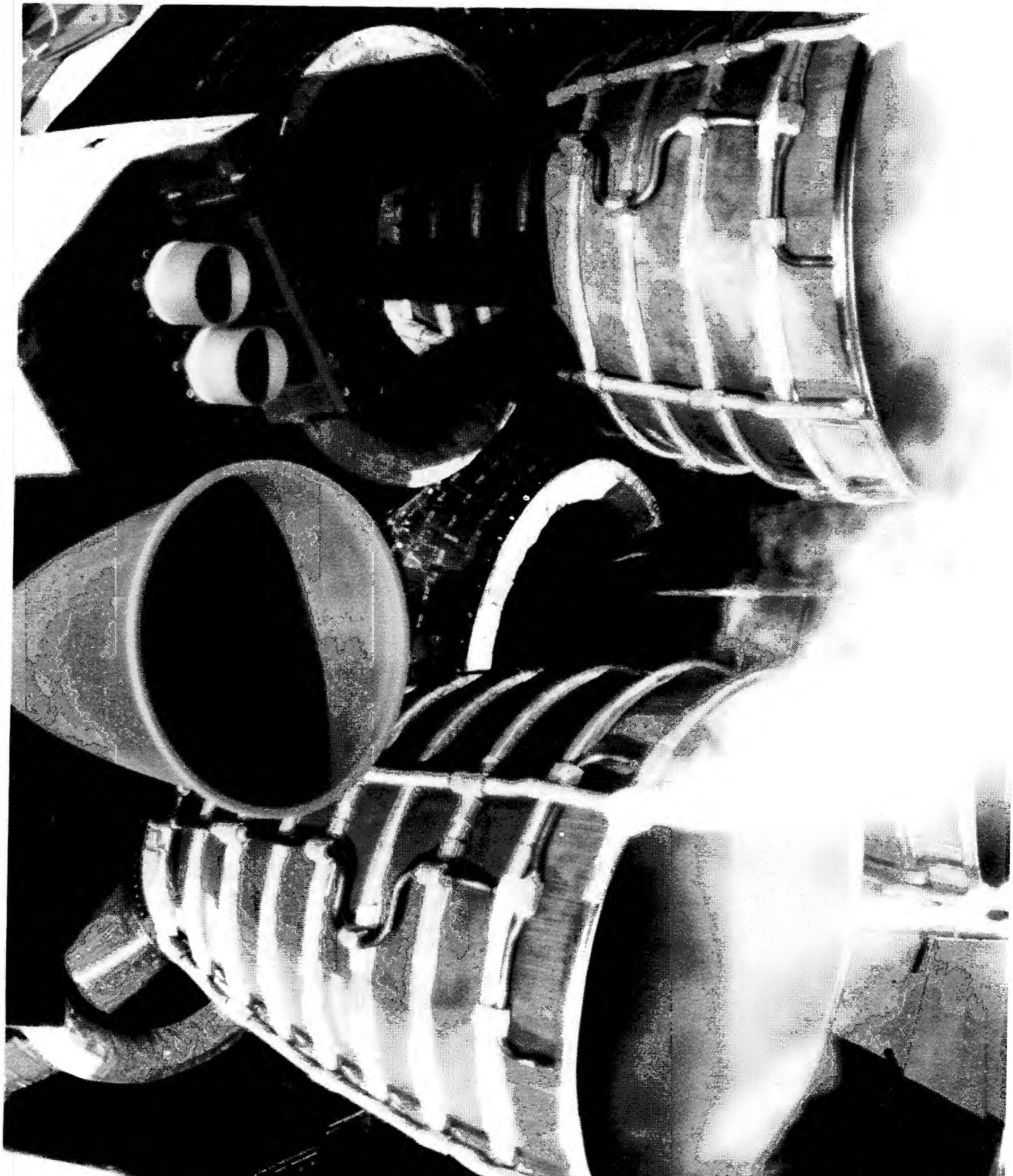
No TPS anomalies occurred on the External Tank acreage areas. GOX vapors were blown away from the vehicle by southerly winds.

Overall view of the LH2 tank +Y+Z quadrant. Minimal ice/frost had formed on the ET/ORB LO2 umbilical.



Overall view of ET-32 (LWT 25) and SRB BI035 -Z sides

4-inch orange GSE tile shim protrudes from the 4th row of black tiles aft of the RH leading edge RCC panel #14.



Overall view of SSME's. Note frost line on the engine mounted heat shield interface of SSME #2.

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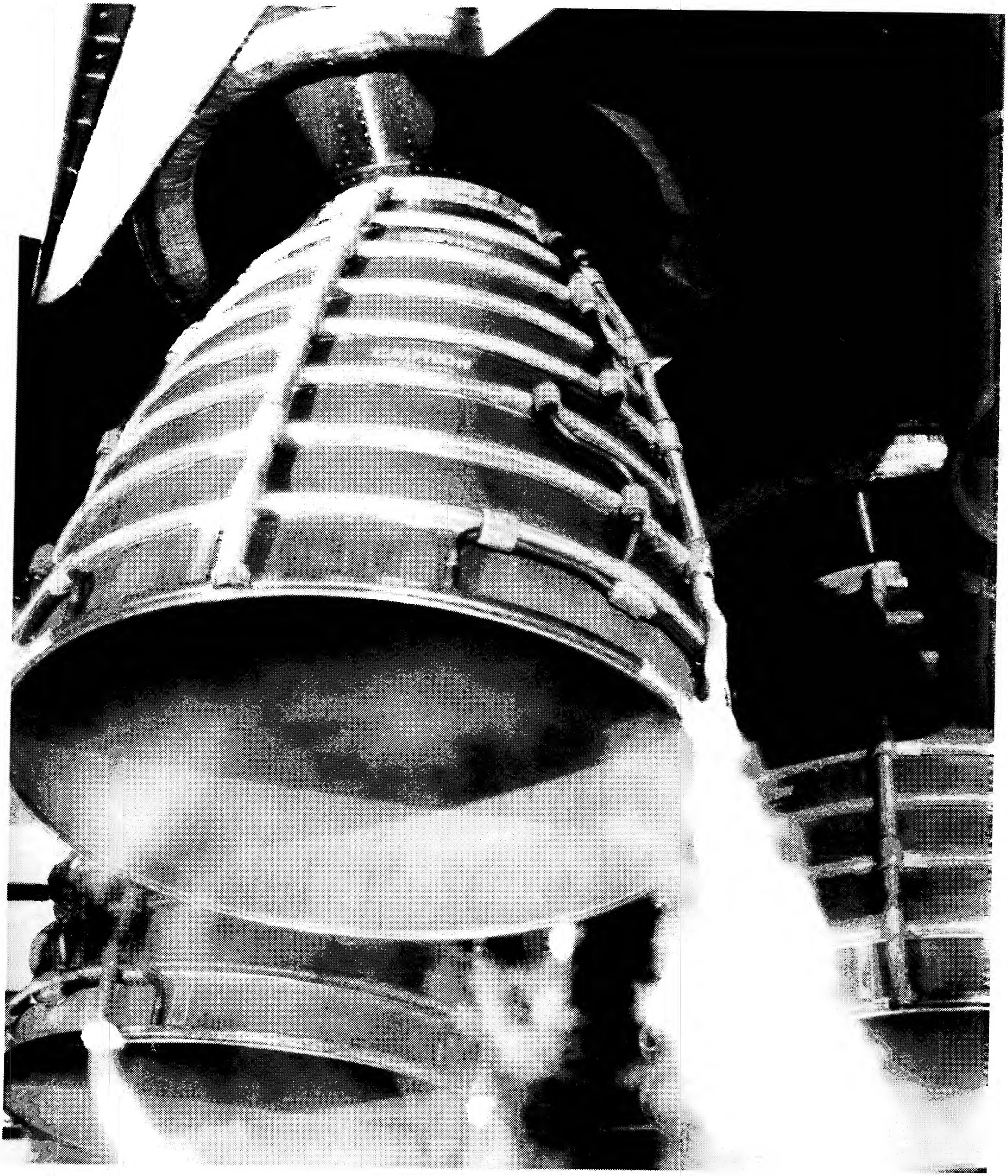
COLOR PHOTOGRAPH



GOX vapors from the drain line are blown into the SSME nozzle by wind and may be misconstrued as a leaking SSME LO2 valve.

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COLOR PHOTOGRAPH

Ice formed on the aft side of the LO2 umbilical. Ice is present in the LH2 recirc line bellows, but not in the feedline bellows Note stream of condensate falling from the manhole cover (arrow).

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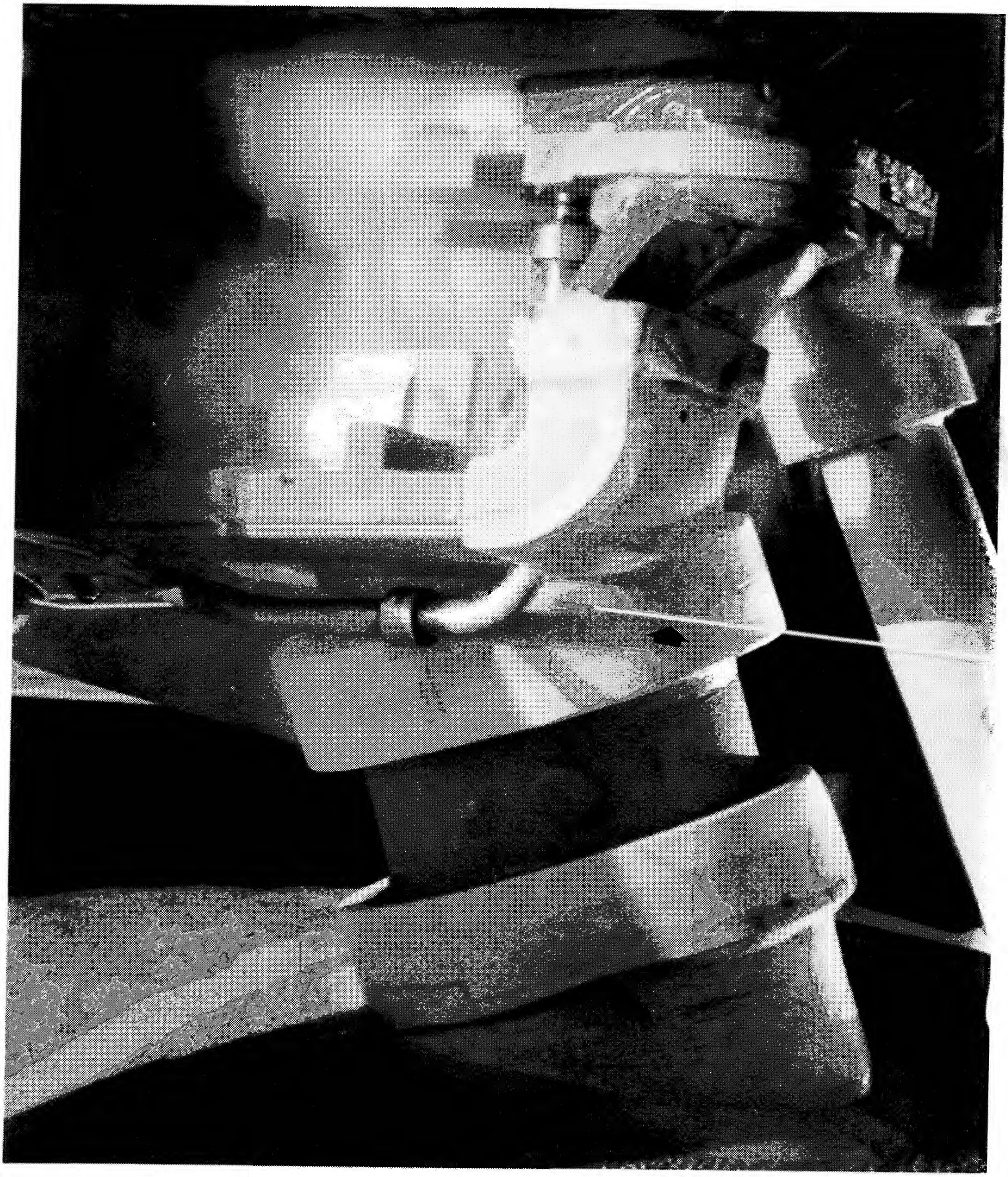

Ice formation on the LH2 umbilical and purge vent vapors are normal. Note retract lanyard for GH2 detection system (arrow).

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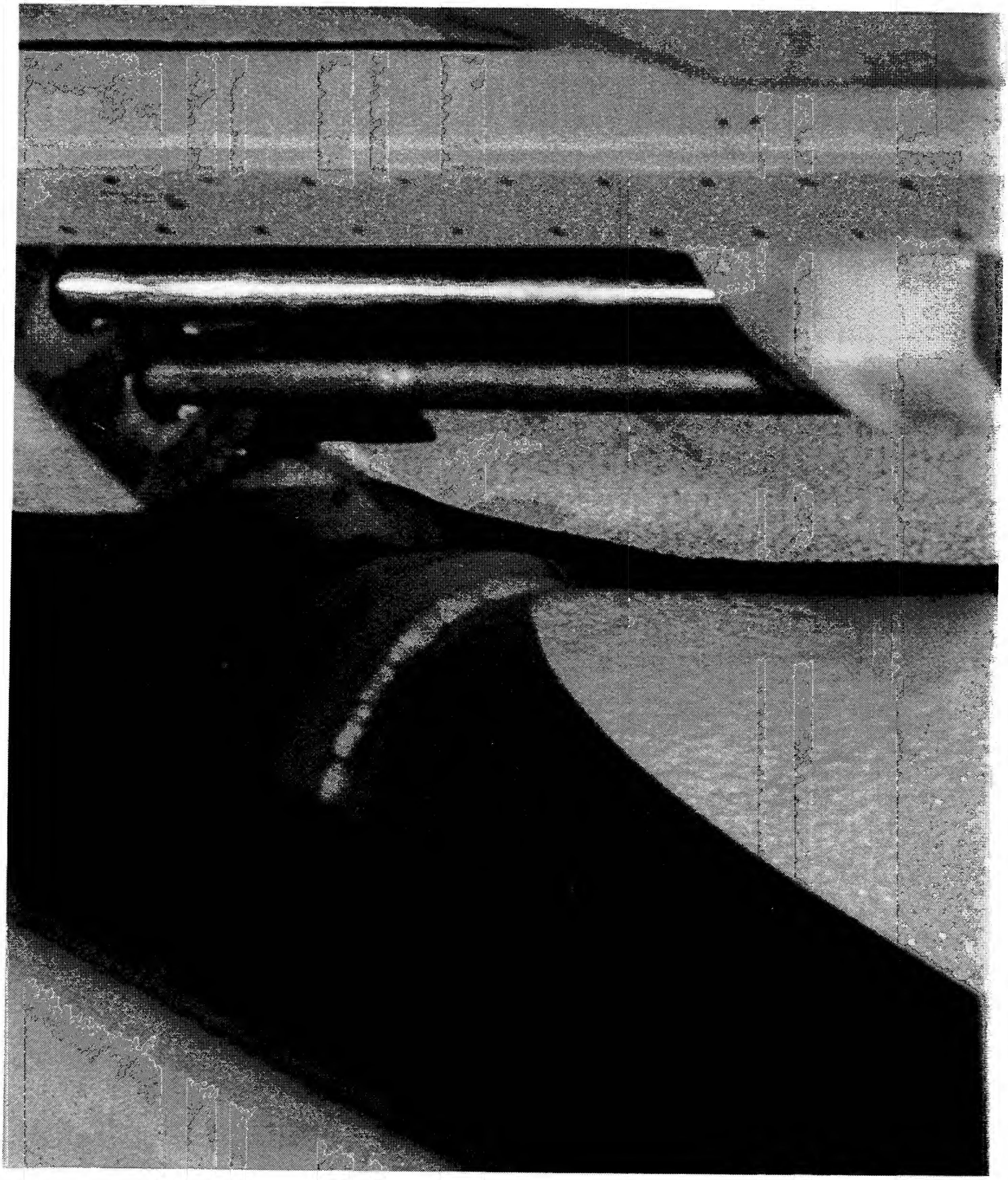
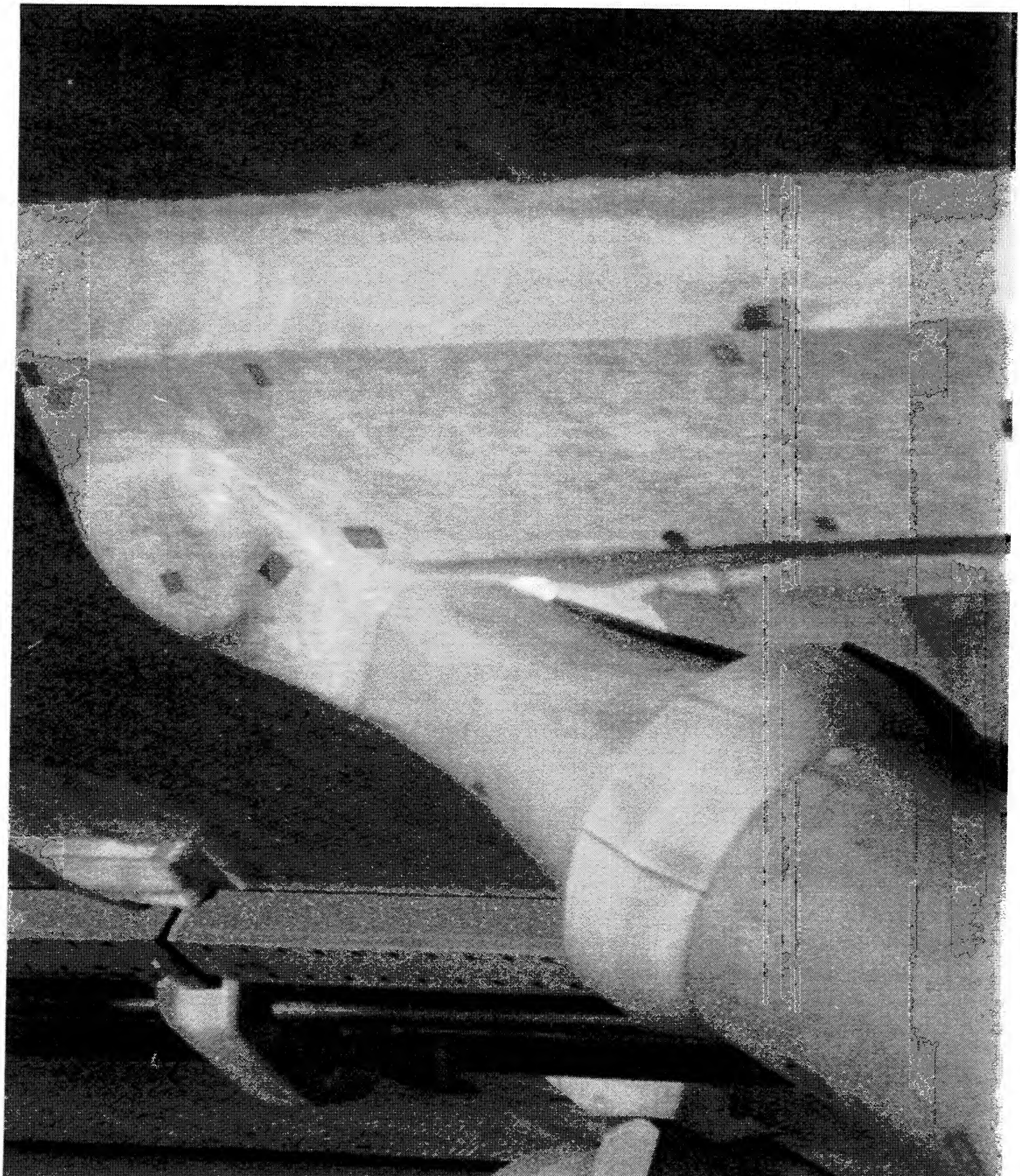


Hard ice has formed in the LO2 feedline lower bellows



A small TPS crack caused a frost spot to form in the thrust strut-to-longeron interface

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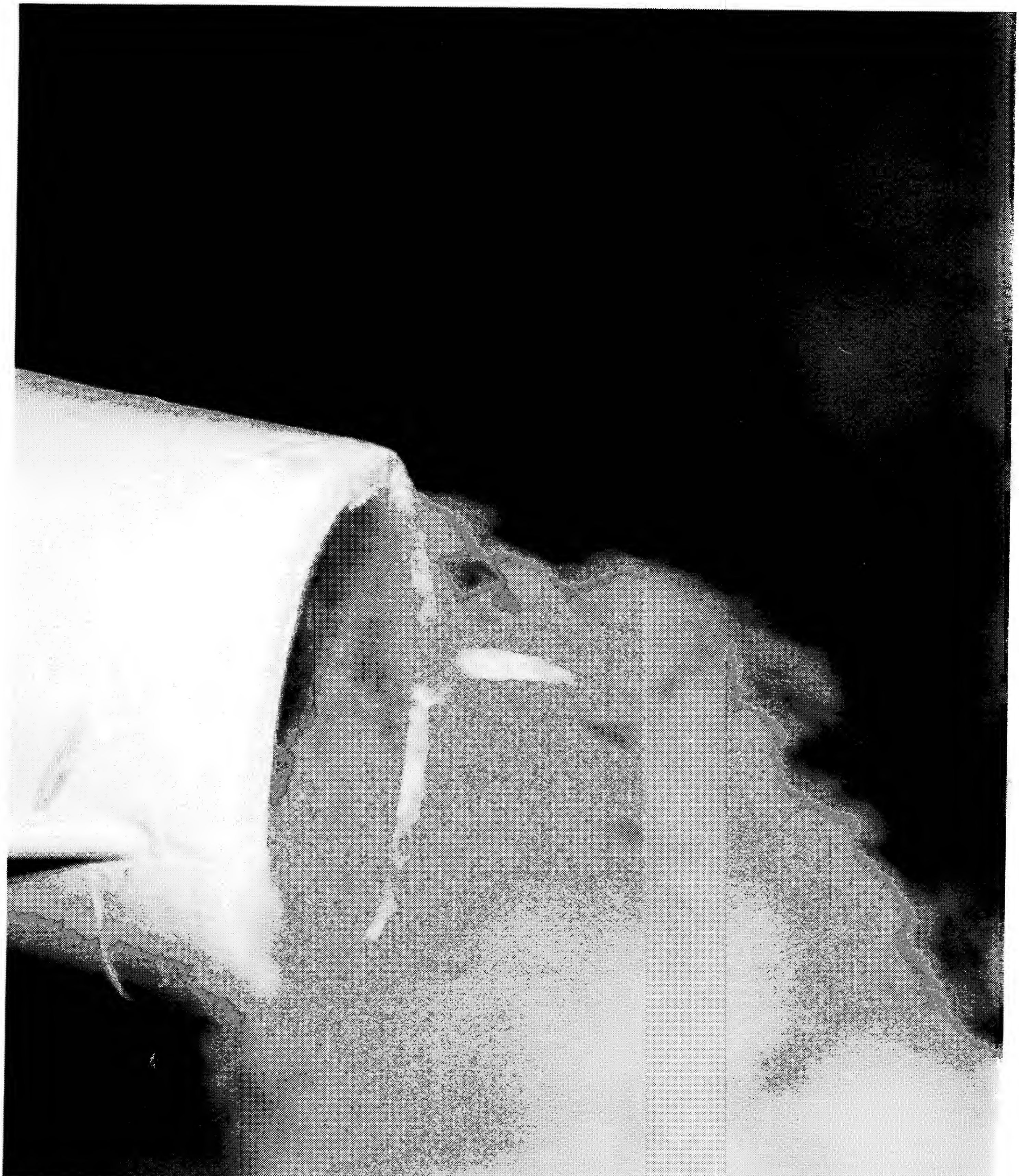
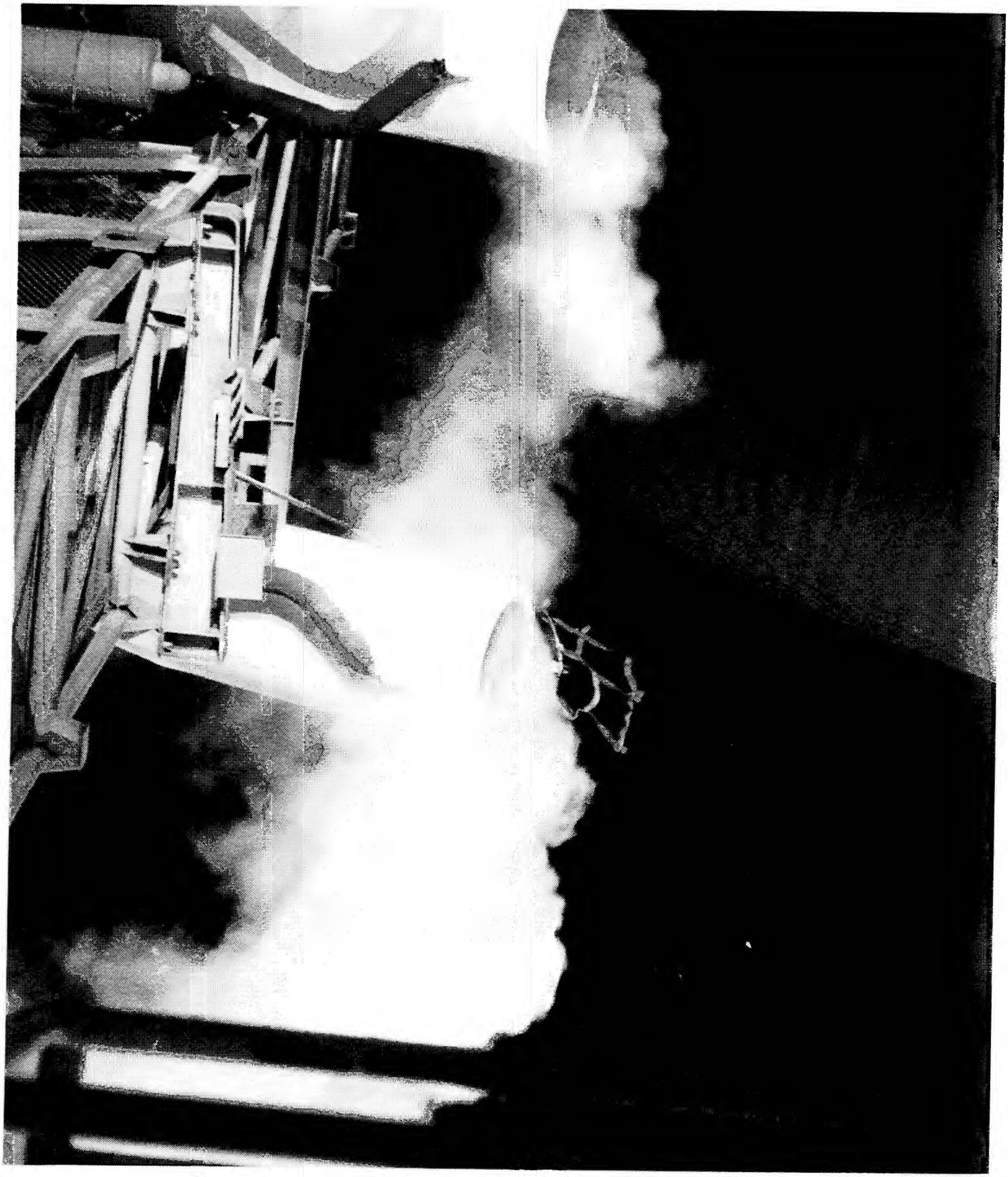


Omitting the hydro diverter on the north GOX vent duct caused dripping water/condensate to form 8-inch icicles



Successful removal of the icicles by the Ice Team prevented TPS damage on the vehicle from falling icicles.

Icicles, with an estimated density of 30 pounds per cubic foot, were removed from the north GOX vent duct by the Ice Team

4.6 POST DRAIN INSPECTION

The STS-32R launch was scrubbed due to weather constraints at the RTLS abort site. Both the LH2 and LO2 tanks had been filled to 100 percent. A post-drain inspection was performed at Pad 39A from 1345 to 1515 hours on 8 January 1990. Since a 24-hour Scrub Turnaround was initiated, the post drain inspection and the preflight pad debris inspection were combined.

The tumble valve cover exhibited no anomalies.

No TPS damage, such as divots or cracks on the tank acreage, were visible except for a small amount of ice/frost formation on the leak check port closeout on the ET aft dome siphon manhole. Some vapors also emanated from the port closeout.

Ice had accumulated at both LH and RH SRB cable tray to upper strut fairing interfaces.

A crack, 12 inches in length, was visible in the +Y LH2 longeron TPS. This has typically occurred after detanking other vehicles and was acceptable per NSTS-08303.

A small amount of solid ice still remained in the LH2 feedline lower bellows and LH2 recirculation line lower bellows. Solid ice (6 inches long) was attached to five of the LH2 umbilical purge vents. Ice 1 inch thick still covered EB-7 and EB-8.

No ice/frost was visible on the LO2 ET/ORB umbilical. A solid ring of ice filled the LO2 feedline lower bellows. Ice was present in all feedline support brackets with heavy amounts of ice in the lower two brackets. The LO2 feedline support brackets could not be inspected in detail due to the heavy accumulation of ice.

All of this ice/frost has occurred previously on other vehicles and was acceptable per NSTS-08303.

There was no damage to the Orbiter or SRB TPS.

The orange GSE tile shim gage on the RH wing lower surface had not changed since reported during the Ice Team inspection.

The SRB sound suppression water troughs were full.

NASA Technical Memorandum TM 102787

Debris/Ice/TPS Assessment And Photographic Analysis For Shuttle Mission STS-32R

March 1990

(NASA-TM-102787) DEBRIX/ICE/TPS ASSESSMENT AND PHOTOGRAPHIC ANALYSIS OF SHUTTLE MISSION STS-32R (NASA) 233 p CSCL 22B

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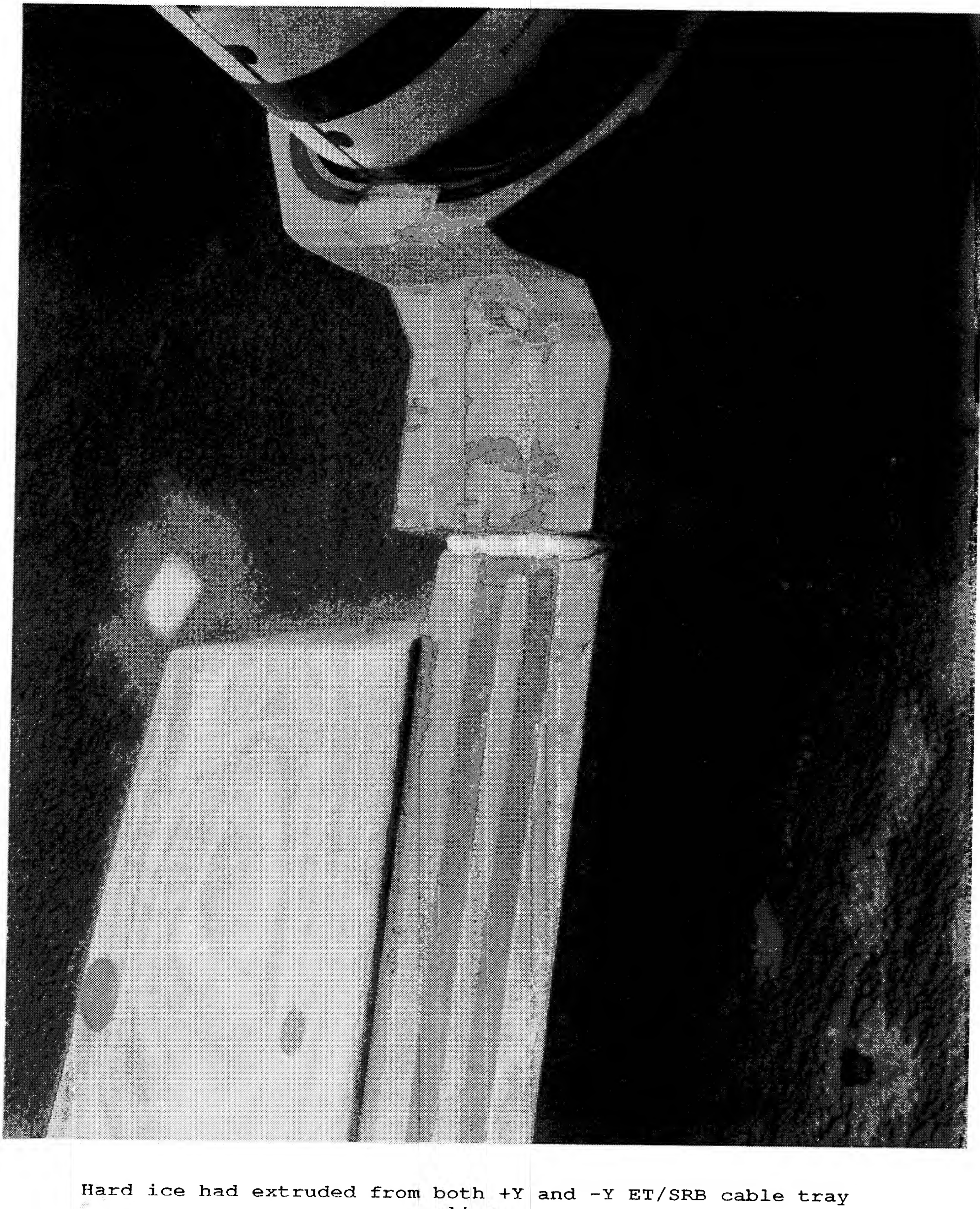
National Aeronautics and
Space Administration

Hard ice remained on the LH2 ET/ORB umbilical purge vents after the tank had been drained

Although no ice/frost was present in the LH2 feedline bellows after drain, hard ice was still attached to the purge vents.



Hard ice had extruded from both +Y and -Y ET/SRB cable tray splices

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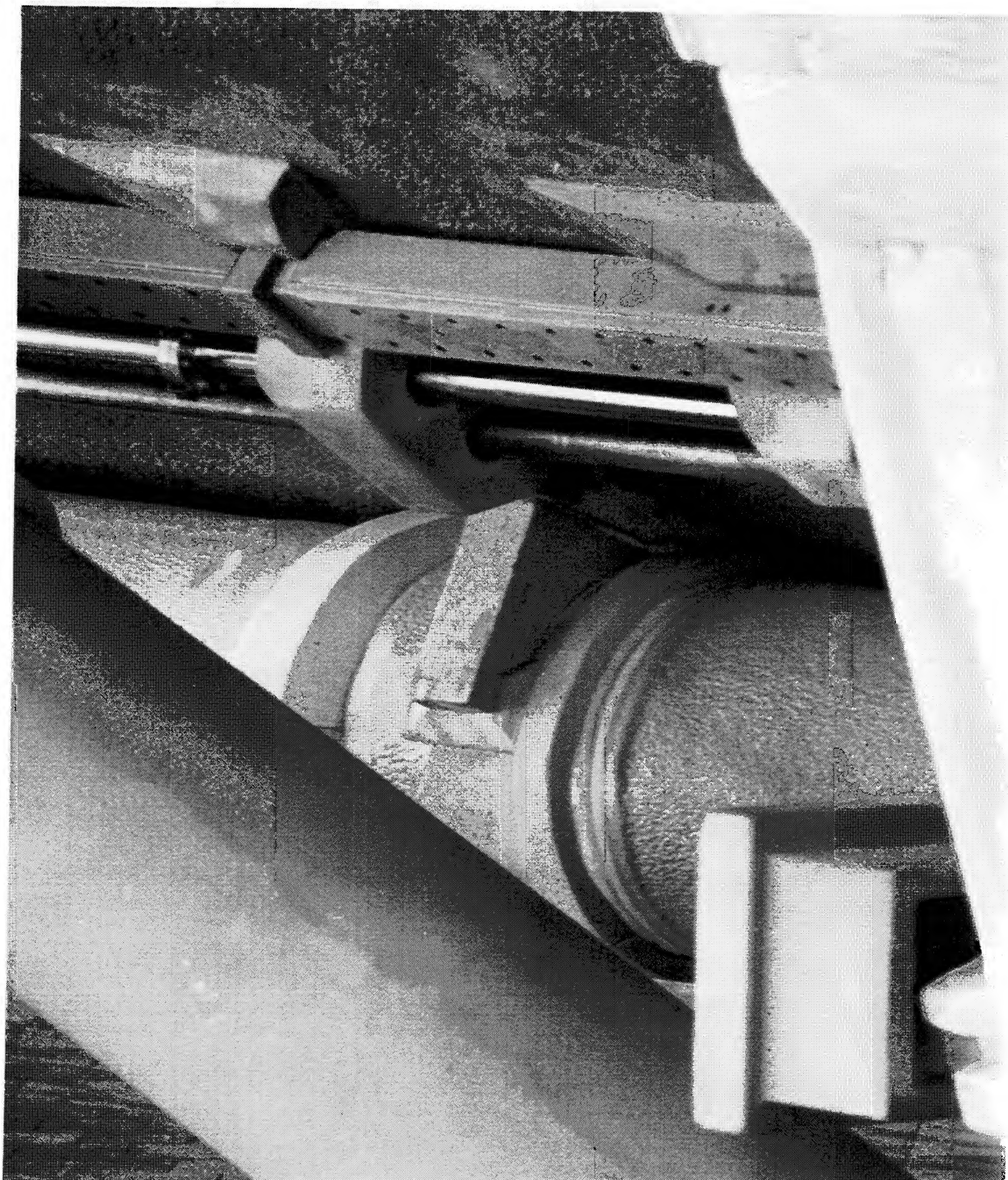


Hard ice was visible in the LO2 feedline support bracket and lower bellows

5.0 LAUNCH

STS-32R was launched at 0735 EST on 9 January 1990.

5.1 ICE/FROST INSPECTION

The Ice/Frost Inspection of the cryo loaded vehicle was performed on 9 January 1990 from 0400 to 0520 hours during the two hour built-in-hold at T-3 hours in the countdown. There were no violations of NSTS-08303 or the Launch Commit Criteria. Ambient weather conditions at the time of the inspection were:

Temperature:	51.8 F
Relative Humidity:	100 %
Wind Speed:	5.5 Knots
Wind Direction:	276 Degrees

The portable STI infrared scanner was utilized to obtain surface temperature measurements for an overall thermal assessment of the vehicle, as shown in Figure 6 and 7.

5.2 ORBITER OBSERVATIONS

No Orbiter tile anomalies, other than those documented during the scrubbed launch attempt, were observed. The average Orbiter surface temperature was recorded as 55 degrees F. The average surface temperatures of the SSME engine mounted heat shields were measured at 50 degrees F for SSME #1, 46 degrees F for SSME #2, and 50 degrees F for SSME #3. Frost lines were present on the SSME engine mounted heat shield interface: the entire circumference except for 12 - 2 o'clock on SSME #1; the entire circumference except for 10 - 12 o'clock on SSME #2. There was no ice or frost on the SSME #3 heatshield.

5.3 SRB OBSERVATIONS

No SRB anomalies or loose ablator/cork were observed. The STI portable infrared scanner recorded RH and LH SRB case surface temperatures between 52 to 57 degrees F. Temperatures in the area of the SRB field joint heaters ranged from 73 to 76 degrees F. The predicted Propellant Mean Bulk Temperature (PMBT) supplied by MTI was 65 degrees F.

FIGURE 6. **INFRA RED SCANNER SSV SUMMARY DATA**

TIME: 0400-0520
DATE: 1/9/90
VEH. STS- 32R

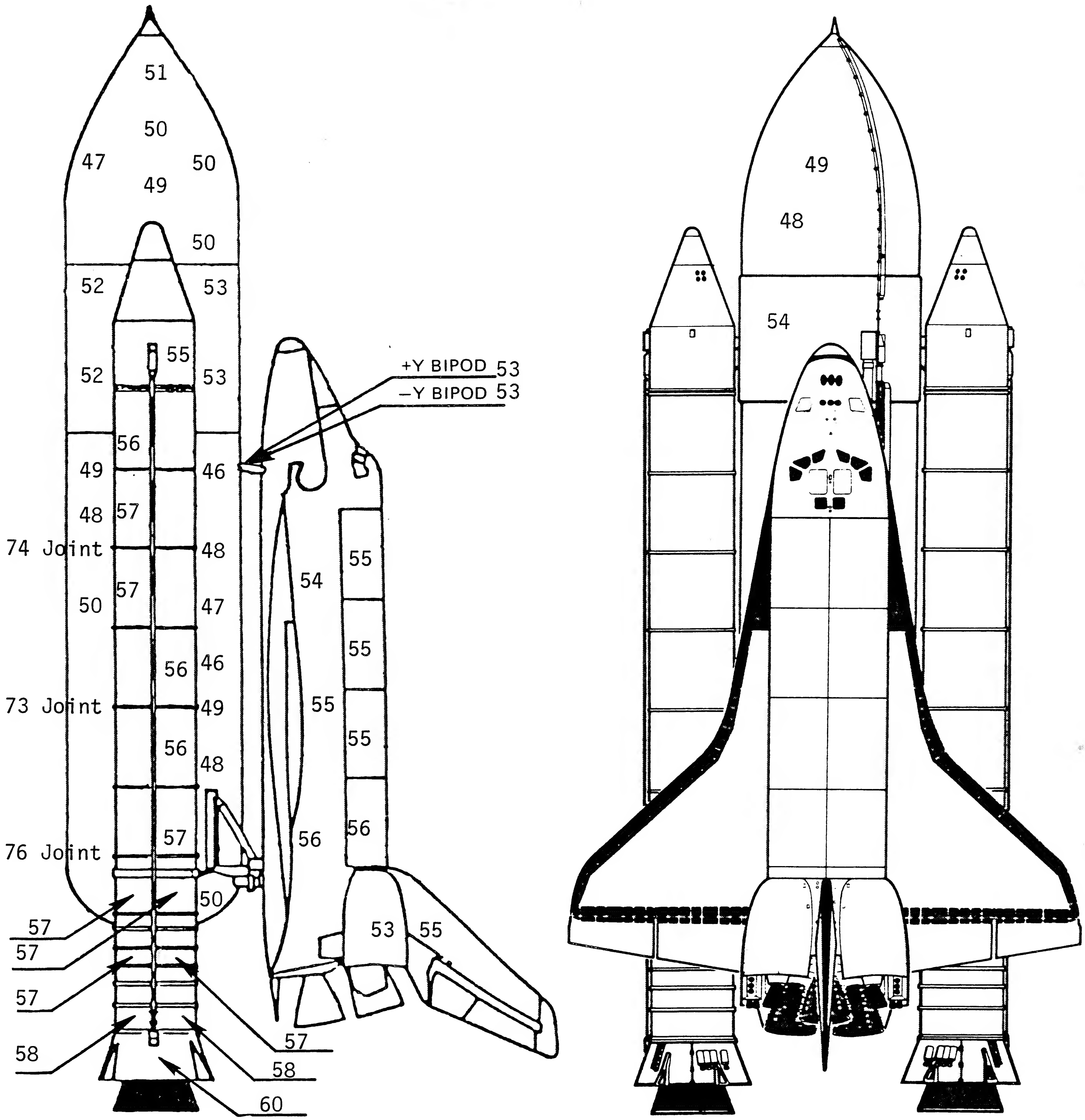
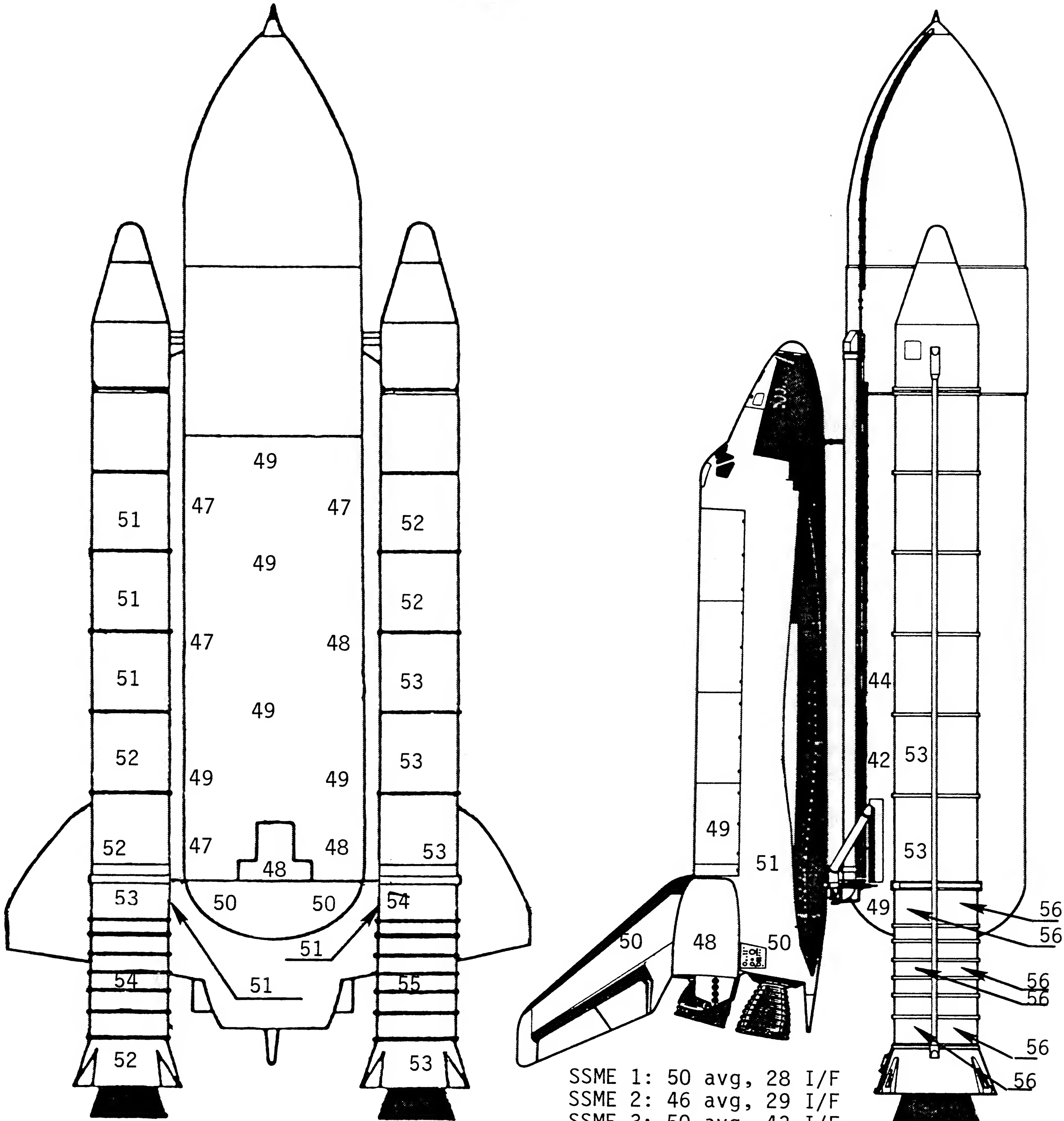


FIGURE 7 **INFRA RED SCANNER SSV SUMMARY DATA**

TIME: 0400-0520
DATE: 1/9/90
VEH. STS- 32R



SSME 1: 50 avg, 28 I/F
SSME 2: 46 avg, 29 I/F
SSME 3: 50 avg, 43 I/F

5.4 EXTERNAL TANK OBSERVATIONS

The ice/frost prediction computer program was run from 2253 to 0735 hours and the results tabulated in Figures 8-11. The program predicted condensate with no ice accumulation on all TPS acreage surfaces.

Acreage condensate was present on the LO2 tank, Intertank (run on), and LH2 tank. The IR scanner measured an average surface temperature of 49 degrees F on the LO2 tank, 53 degrees F on the Intertank, and 47 degrees F on the upper and lower LH2 tank.

One TPS anomaly occurred on the aft dome apex. A SLA vent closeout 2 inches in diameter was protruding 3/8 inch. PR TS-0063 was taken and dispositioned with MRB approval to fly-as-is.

An average amount of condensate trickled down the LH2 tank and ran off the aft dome. There was no acreage ice/frost, defects, or TPS anomalies. A small frost spot appeared on the aft corner of the third hardpoint closeout. A 1-inch diameter TPS repair on the acreage +Y side, 4 feet forward of the longeron and 1 foot outboard of the cable tray, was covered by frost.

Ice/Frost covered the lower EB fittings outboard to the strut pin hole with condensate on the rest of the fitting. The struts were dry and were not covered by ice.

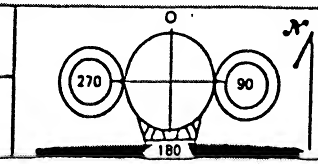
The -Y longeron exhibited a 2 inch long line (iceball) on the sanded section 2 feet below the attach point. TPS in the -Y thrust strut to LH2 tank interface area was cracked, but not filled with ice/frost. Small cracks, which occurred in the same area on the +Y side, were filled with frost. Ice filled the interface of both ET/SRB cable trays at the +Z side of the upper strut fairings.

The LO2 ET/ORB umbilical exhibited normal accumulations of frost on both the aft and inboard sides. Frost fingers, below average in size, had formed on the purge vents and normal venting was occurring.

The LH2 feedline bellows were covered with ice and frost. Frost covered the aft inboard side of the feedline. Ice/frost had formed in the LH2 recirculation line bellows. Ice/frost accumulation on the LH2 ET/ORB umbilical was greater than normal. The size of the purge vent frost fingers was average. This coverage was acceptable per NSTS-08303. There were no unusual vapors emanating from the umbilicals or any evidence of leakage.

Hard ice and some vapors were present in the LO2 feedline lower bellows. The upper bellows were filled with normal-to-heavy hard ice. All LO2 feedline support brackets were filled

STS – 32R	TEST: S0007 Launch	DATE: 1/8/90	T–0 TIME: 0735 DATE: 1/9/90



ORBITER	ET	SRB	MLP	PAD	LO_2	LH_2
OV– 102	32	B1035	3	39A	CHILLDOWN TIME: FAST FILL TIME: 0006 SLOW FILL TIME: 2353 REPLENISH TIME: 0349	CHILLDOWN TIME: 2315 FAST FILL TIME: 2347 SLOW FILL TIME: 2324 REPLENISH TIME: 0109

LOCAL TIME	CONDITIONS					LO_2 TANK STA 370 TO 540					LO_2 TANK STA 550 TO 852					LH_2 TANK STA 1130 TO 1380					LH_2 TANK STA 1380 TO 2058				
	TEMP. °F	REL HUM. %	DEW PT °F	WIND VEL KNTS	WIND DIR DEG	REGION	LOCAL VEL KNTS	SOFI TEMP °F	COND RATE IN/HR	ICE RATE IN/HR	REGION	LOCAL VEL KNTS	SOFI TEMP °F	COND RATE IN/HR	ICE RATE IN/HR	REGION	LOCAL VEL KNTS	SOFI TEMP °F	COND RATE IN/HR	ICE RATE IN/HR	REGION	LOCAL VEL KNTS	SOFI TEMP °F	COND RATE IN/HR	ICE RATE IN/HR
2253	59.6	79	53.11	7	267	II	4.13	46.93	.0017	-.0690	II	4.13	41.29	.0029	-.0417	II	3.01	36.51	.0029	-.0165	II	8.47	46.66	.0033	-.1107
2300	59.7	79	53.21	6	273	II	3.54	46.07	.0017	-.0589	II	3.54	39.81	.0028	-.0318	II	2.58	34.71	.0028	-.0092	II	7.26	45.59	.0033	-.0911
2315	58.3	82	52.84	8	281	II	4.72	46.87	.0019	-.0749	II	3.44	37.15	.0031	-.0204	II	3.44	37.15	.0031	-.0204	II	9.68	46.80	.0035	-.1237
2330	57.6	84	52.81	11	267	II	6.49	48.19	.0020	-.1023	II	6.49	44.11	.0033	-.0744	II	4.73	40.24	.0034	-.0402	II	13.31	48.38	.0035	-.1777
2345	56.8	84	52.02	7	270	II	4.13	44.78	.0019	-.0584	II	4.13	39.02	.0030	-.0313	II	3.01	34.09	.0029	-.0078	II	8.47	44.60	.0036	-.0939
0000	56.0	86	51.87	7	263	II	4.13	44.25	.0020	-.0558	II	4.13	38.46	.0031	-.0287	II	3.01	33.51	.0030	-.0056	II	8.47	44.09	.0037	-.0899
0015	55.4	87	51.59	7	273	II	4.13	43.76	.0020	-.0534	II	4.13	37.94	.0031	-.0264	II	3.01	32.99	.0030	-.0036	II	8.47	43.62	.0038	-.0861
0030	55.2	88	51.70	6	280	II	3.54	42.68	.0020	-.0438	II	3.54	36.21	.0030	-.0170	II	2.58	32.00	.0028	-.0000	II	7.26	42.32	.0038	-.0679
0045	54.0	91	51.42	8	278	II	4.72	43.73	.0022	-.0580	II	4.72	38.39	.0034	-.0309	II	3.44	33.63	.0032	-.0065	II	9.68	43.78	.0041	-.0967
0100	54.0	92	51.72	6	271	II	3.54	41.98	.0022	-.0409	II	3.54	35.48	.0031	-.0141	III	2.58	31.18	.0029	+.0060	II	7.26	41.68	.0040	-.0635
0115	54.5	93	52.51	7	267	II	4.13	43.77	.0023	-.0535	II	4.13	37.94	.0034	-.0264	II	3.01	32.91	.0032	-.0034	II	8.47	43.69	.0043	-.0868
0130	54.0	95	52.60	6	271	II	3.54	42.47	.0023	-.0430	II	3.54	35.98	.0033	-.0161	III	2.58	31.99	.0030	+.0034	II	7.26	42.20	.0043	-.0672
0145	53.5	95	52.10	7	280	II	4.13	42.96	.0024	-.0496	II	4.13	37.10	.0034	-.0226	II	3.01	32.07	.0033	-.0002	II	8.47	42.91	.0044	-.0807
0200	52.8	96	51.68	7	279	II	4.13	42.33	.0024	-.0466	II	4.13	36.43	.0034	-.0197	III	3.01	31.99	.0032	+.0012	II	8.47	42.29	.0044	-.0758
0215	52.4	97	52.40	5	271	II	2.95	39.60	.0022	-.0277	II	2.95	32.34	.0031	-.0012	III	2.15	27.67	.0028	+.0162	II	6.05	39.02	.0041	-.0401

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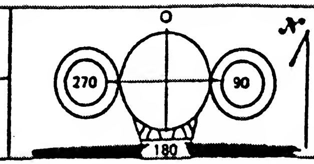
FIGURE 8. Ice/Frost Computer Predictions

STS – 32R	TEST: S0007 Launch	DATE: 1/9/90	T–0 TIME 0735 DATE 1/9/90
ORBITER OV–102 / ET 32 / SRB B1035 / MLP 3 / PAD 39A	LO_2 CHILLDOWN TIME: FAST FILL TIME: 0006 SLOW FILL TIME: 2353 REPLENISH TIME: 0349	LH_2 CHILLDOWN TIME: 2315 FAST FILL TIME: 2347 SLOW FILL TIME: 2324 REPLENISH TIME: 0109	



LOCAL TIME	CONDITIONS TEMP. °F	REL. HUM. %	DEW PT °F	WIND VEL. KNTS	WIND DIR DEG	LO_2 TANK STA 370 TO 540 REGION	LOCAL VEL KNTS	SOFI TEMP °F	COND RATE IN/HR	ICE RATE IN/HR	LO_2 TANK STA 550 TO 852 REGION	LOCAL VEL KNTS	SOFI TEMP °F	COND RATE IN/HR	ICE RATE IN/HR	LH_2 TANK STA 1130 TO 1380 REGION	LOCAL VEL KNTS	SOFI TEMP °F	COND RATE IN/HR	ICE RATE IN/HR	LH_2 TANK STA 1380 TO 2058 REGION	LOCAL VEL KNTS	SOFI TEMP °F	COND RATE IN/HR	ICE RATE IN/HR
0230	52.5	98	51.95	5	266	II	2.95	39.87	.0022	-.0287	II	2.95	32.57	.0031	-.0022	III	2.15	27.95	.0028	+.0154	II	6.05	39.30	.0042	-.0417
0245	52.5	98	51.95	6	267	II	3.54	41.23	.0024	-.0377	II	3.54	34.67	.0033	-.0109	III	2.58	30.37	.0030	+.0089	II	7.26	41.00	.0044	-.0589
0300	52.3	99	52.3	6	278	II	3.54	41.15	.0024	-.0374	II	3.54	34.59	.0033	-.0106	III	2.58	30.29	.0030	+.0092	II	7.26	40.93	.0044	-.0584
0315	51.9	99	51.63	6	271	II	3.54	40.69	.0024	-.0354	II	3.54	34.10	.0033	-.0087	III	2.58	29.81	.0030	+.0107	II	7.26	40.47	.0044	-.0553
0330	51.8	100	51.80	5	265	II	2.95	39.36	.0023	-.0268	II	2.95	31.99	.0031	-.0002	III	2.15	27.40	.0028	+.0170	II	6.05	38.80	.0043	-.0389
0345	51.6	100	51.6	6	272	II	3.54	40.50	.0024	-.0346	II	3.54	33.90	.0033	-.0079	III	2.58	29.61	.0030	+.0104	II	7.26	40.29	.0044	-.0541
0400	51.7	100	51.7	6	275	II	3.54	40.62	.0024	-.0357	II	3.54	34.02	.0033	-.0084	III	2.58	29.73	.0030	+.0110	II	7.26	40.41	.0045	-.0549
0415	51.7	101	51.97	4	273	II	2.36	37.59	.0021	-.0180	III	2.36	30.38	.0028	+.0083	III	1.72	24.96	.0026	+.0235	II	4.84	36.51	.0040	-.0221
0430	51.8	101	52.07	5	268	II	2.95	39.51	.0023	-.0274	II	2.95	31.99	.0032	-.0007	III	2.15	27.56	.0029	+.0166	II	6.05	38.97	.0043	-.0398
0445	51.6	101	51.87	7	278	II	4.13	41.75	.0026	-.0439	II	4.13	35.82	.0036	-.0170	III	3.01	31.70	.0033	+.0046	II	8.47	41.76	.0047	-.0718
0500	51.6	101	51.87	5	281	II	2.95	39.27	.0023	-.0265	III	2.95	31.99	.0032	+.0000	III	2.15	27.31	.0029	+.0174	II	6.05	38.73	.0043	-.0384
0515	52.2	101	52.47	6	284	II	3.54	41.35	.0025	-.0382	II	3.54	34.79	.0034	-.0114	III	2.58	30.49	.0031	+.0086	II	7.26	41.15	.0046	-.0599
0530	51.9	101	52.17	6	280	II	3.54	41.00	.0025	-.0367	III	3.54	34.43	.0034	-.0099	III	2.58	30.12	.0031	+.0098	II	7.26	40.8	.0046	-.5756
0545	50.4	101	50.67	5	286	II	2.95	37.87	.0022	-.0213	III	2.95	31.49	.0030	+.0051	III	2.15	25.84	.0028	+.0215	II	6.05	37.32	.0042	-.0303
0600	51.1	99	50.83	6	284	II	3.54	39.77	.0023	-.0315	II	3.54	33.18	.0033	-.0049	III	2.58	28.86	.0030	+.0030	II	7.26	39.55	.0043	-.0491

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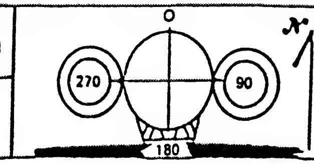
FIGURE 9. Ice/Frost Computer Predictions

STS – 32R	TEST: S0007 Launch	DATE: 1/9/90	T-0 TIME: 0735 DATE: 1/9/90

ORBITER	ET	SRB	MLP	PAD	LO_2	LH_2
OV–102	32	B1035	3	39A	CHILLDOWN TIME: FAST FILL TIME: 0006 SLOW FILL TIME: 2353 REPLENISH TIME: 0349	CHILLDOWN TIME: 2315 FAST FILL TIME: 2347 SLOW FILL TIME: 2324 REPLENISH TIME: 0109



LOCAL TIME	CONDITIONS					LO_2 TANK STA 370 TO 540					LO_2 TANK STA 550 TO 852					LH_2 TANK STA 1130 TO 1380					LH_2 TANK STA 1380 TO 2058				
	TEMP. °F	REL. HUM. %	DEW PT °F	WIND VEL KNTS	WIND DIR DEG	REGION	LOCAL VEL KNTS	SOFI TEMP °F	COND RATE IN/HR	ICE RATE IN/HR	REGION	LOCAL VEL KNTS	SOFI TEMP °F	COND RATE IN/HR	ICE RATE IN/HR	REGION	LOCAL VEL KNTS	SOFI TEMP °F	COND RATE IN/HR	ICE RATE IN/HR	REGION	LOCAL VEL KNTS	SOFI TEMP °F	COND RATE IN/HR	ICE RATE IN/HR
0615	51.2	100	51.2	7	274	II	4.13	41.14	.0025	-.0410	II	4.13	35.18	.0035	-.0142	III	3.01	31.09	.0032	+.0069	II	8.47	41.15	.0046	-.0670
0630	51.3	100	51.3	7	274	II	4.13	41.25	.0025	-.0415	II	4.13	35.30	.0035	-.0149	III	3.01	31.22	.0032	+.0065	II	8.47	41.26	.0046	-.0679
0645	51.5	100	51.5	5	278	II	2.95	39.01	.0023	-.0255	III	2.95	31.99	.0031	+.0006	III	2.15	27.04	.0028	+.0181	II	6.05	38.45	.0042	-.0368
0700	51.3	101	51.2	5	277	II	2.95	38.66	.0022	-.0242	III	2.95	31.99	.0030	+.0006	III	2.15	26.67	.0028	+.0192	II	6.05	38.10	.0042	-.0348
0715	52.2	100	52.2	4	253	II	2.36	38.04	.0021	-.0194	III	2.36	30.82	.0028	+.0069	III	1.72	25.44	.0026	+.0223	II	4.84	36.94	.0040	-.0243
0730	52.7	101	52.97	4	238	II	2.36	38.79	.0022	-.0219	III	2.36	31.99	.0028	+.0022	III	1.26	26.17	.0027	+.0218	II	5.44	38.95	.0043	.0370
0735	53.2	101	53.47	3	241	II	1.77	36.96	.0020	-.0138	III	1.77	28.56	.0026	+.0124	III	0.96	26.78	.0027	+.0120	II	4.08	36.36	.0039	.0192
AVG.	53.3	95		6	W			41.51	-				35.08					30.51					41.21		

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FIGURE 10. Ice/Frost Computer Predictions

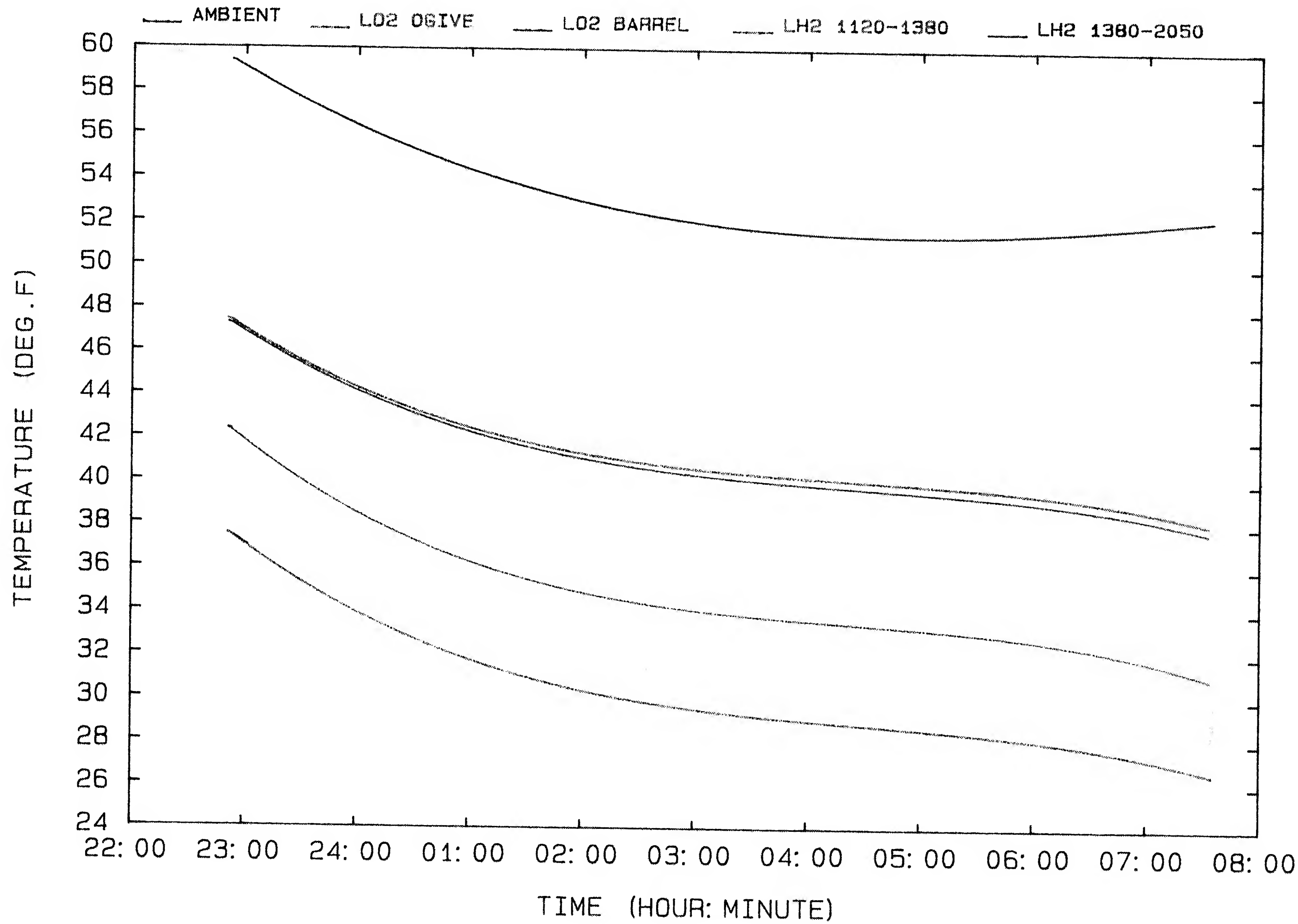


FIGURE 11: EXTERNAL TANK "SURFICE" SURFACE TEMPERATURES

with ice. The amount and thickness of the ice was greater in the aft locations. This ice accumulation was greater than the amount from the previous day's scrubbed launch attempt. The PAL ramp and pressurization line ice/frost ramps were outlined by frost at the acreage interfaces. A 3-inch repair between the barrymounts near the pressurization line at station XT-1282 was ringed with frost.

Run-on condensate from the LO2 tank was present on the intertank. Minor frost had formed around the GUCP, but there was no sign of leakage. Ice/frost accumulated in the -Y-Z stringers at the LO2 tank-to-intertank flange. A frost spot 1.5 inches in diameter formed on the LH2 tank-to-intertank flange between the bipods.

The tumble valve cover, which was not replaced during the recycle, remained intact with no sign of degradation. No TPS defects or anomalies were visible on the LO2 tank. No condensate was present on the ogive. The prevailing wind was out of the north-northwest causing the GOX vent vapors to pass within 4 feet of the ogive, but no ice formed in the ice-free zone of the LO2 tank.

The ET/ORB hydrogen detection sensor tygon tubing was not reinstalled after the scrub due to lack of RSS access to the vehicle.

The summary of Ice/Frost Team observation anomalies consists of 12 OTV recorded items:

Anomaly 009 recorded a PDL foam plug protruding from the LH2 tank aft dome apex. The plug is approximately 2 inches in diameter and protrudes 1/4 to 3/8 inch beyond the outer mold line and is surrounded by ice. PR ET-32-TS-0063 was taken and dispositioned with MRB approval to use-as-is.

Anomaly 010 documented an ice/frost formation on the -Y gusset clip closeout. This condition was acceptable per NSTS-08303.

Some venting and ice/frost formation in the TPS crack at the +Y thrust strut to LH2 tank interface was documented on Anomaly 011. This condition was acceptable per NSTS-08303.

Anomaly 012 reported the accumulation of ice at the ET/ORB LH2 umbilical interface. The ice accumulation was more than usually observed during previous cryoloads, but was acceptable per NSTS-08303.

Anomaly 013 documented ice/frost fingers on both ET/ORB LH2 and LO2 purge vents. This condition has occurred on previous launches and was acceptable per NSTS-08303.

Anomaly 014, taken for information only, documented uneven venting of vapors from the GOX vent ducts. The flow from the north duct was greater.

The accumulation of ice/frost in the LO2 feedline bellows and in the feedline support brackets at all stations was documented on Anomaly 015. This condition has occurred on previous launches and was acceptable per NSTS-08303.

Anomaly 016 recorded ice/frost accumulations on the intertank flanges to both LH2 and LO2 tanks. This condition was acceptable per NSTS-08303.

Anomaly 017 documented an ice/frost formation on the +Z surface of the -Y longeron closeout and was acceptable per NSTS-08303.

A frost ball, approximately 1 inch in diameter, formed at a location 1 foot to the +Y side of the cable tray at station XT-1780. This condition, documented on Anomaly 018, was acceptable per NSTS-08303.

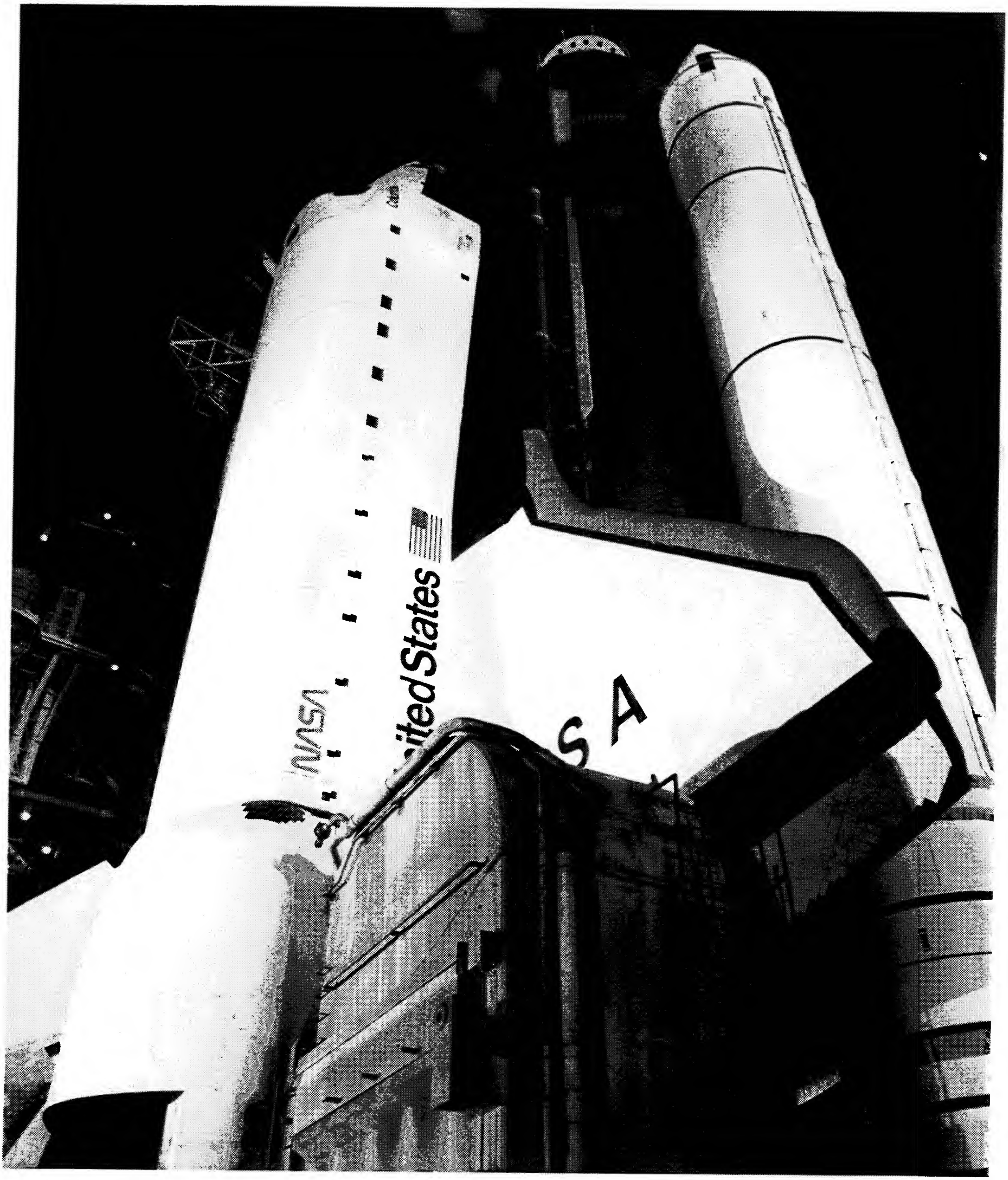
Anomaly 019 recorded the formation of frost along the ice/frost ramp bond line from station XT-1270 to 1528. Frost formation along these bondlines are acceptable per NSTS-08303.

Anomaly 020 documented frost formations on the end of the north GOX vent duct. These formation appeared to be light in texture and density, and were acceptable to the Ice/Debris Team.

5.5 FACILITY OBSERVATIONS

To eliminate the problem with icicle formation on the ends of the GOX vent ducts, which had occurred during the first launch attempt the previous day, the water diverters were removed from Pad B and installed on the Pad A vent ducts. The diverters functioned properly and no icicles formed, though a minor amount of frost accumulated on the duct exit plane.

No new debris concerns had been identified during the ice/frost inspection of the vehicle. There was no apparent leakage anywhere on the GH2 vent line or GUCP. The modification to the GH2 vent line prevented ice from forming but some ice/frost, which was expected, had accumulated on the GUCP legs. Visual and infrared observations of the GOX seals confirmed no leakage. The sound suppression water troughs were full of water per design. There were no facility anomalies.



Overall view of OV-102 Columbia, ET-32 (LWT 25), and BIO35
after the second cryoload

No ice/frost had formed on the acreage in the +Y+Z quadrant though a frost line formed along the PAL ramp

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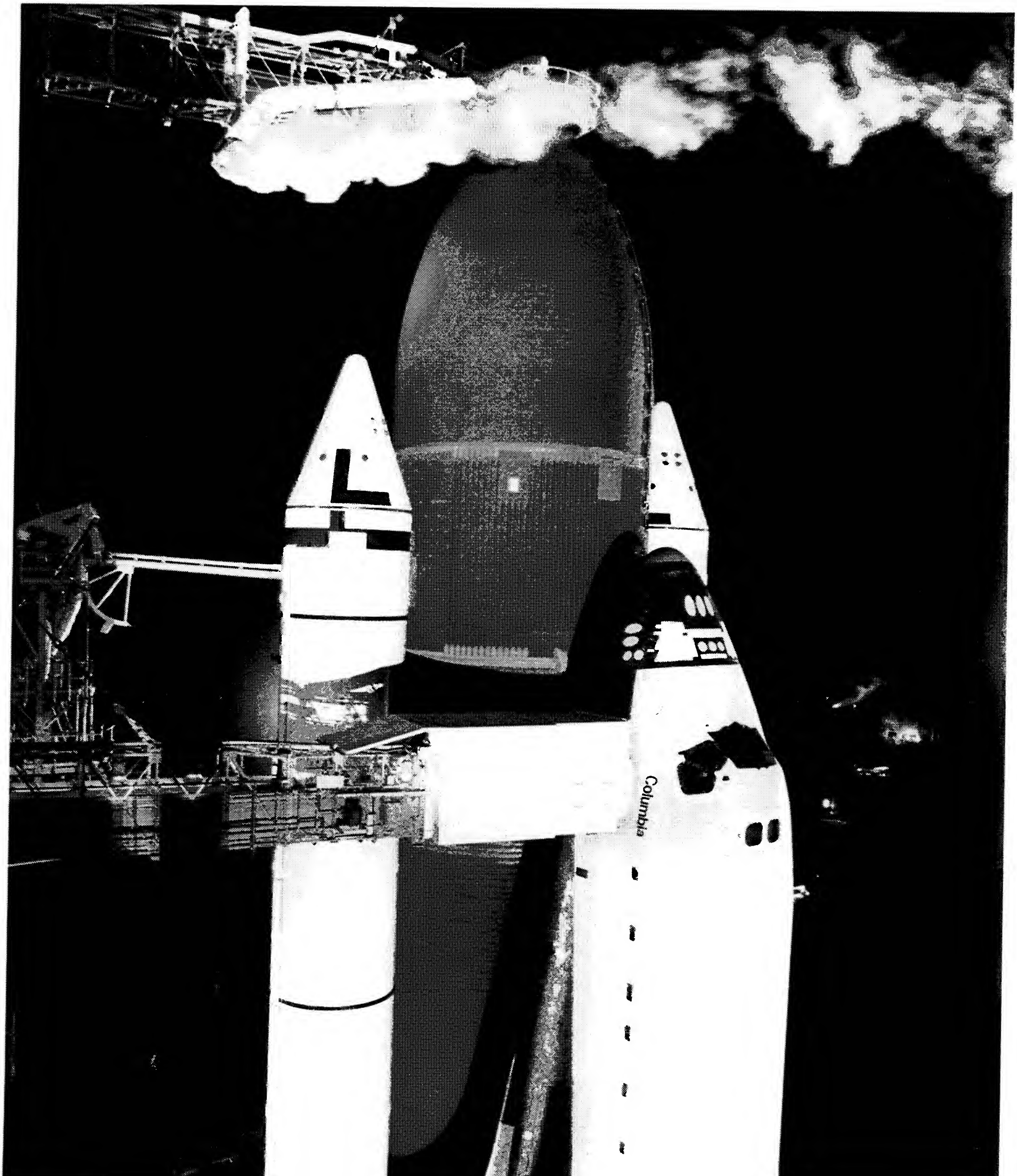
No ice/frost had formed on the acreage in the -Y+Z quadrant



Although westerly winds blew GOX vapors past the LO2 tank ogive, no ice/frost had accumulated in the no-ice region

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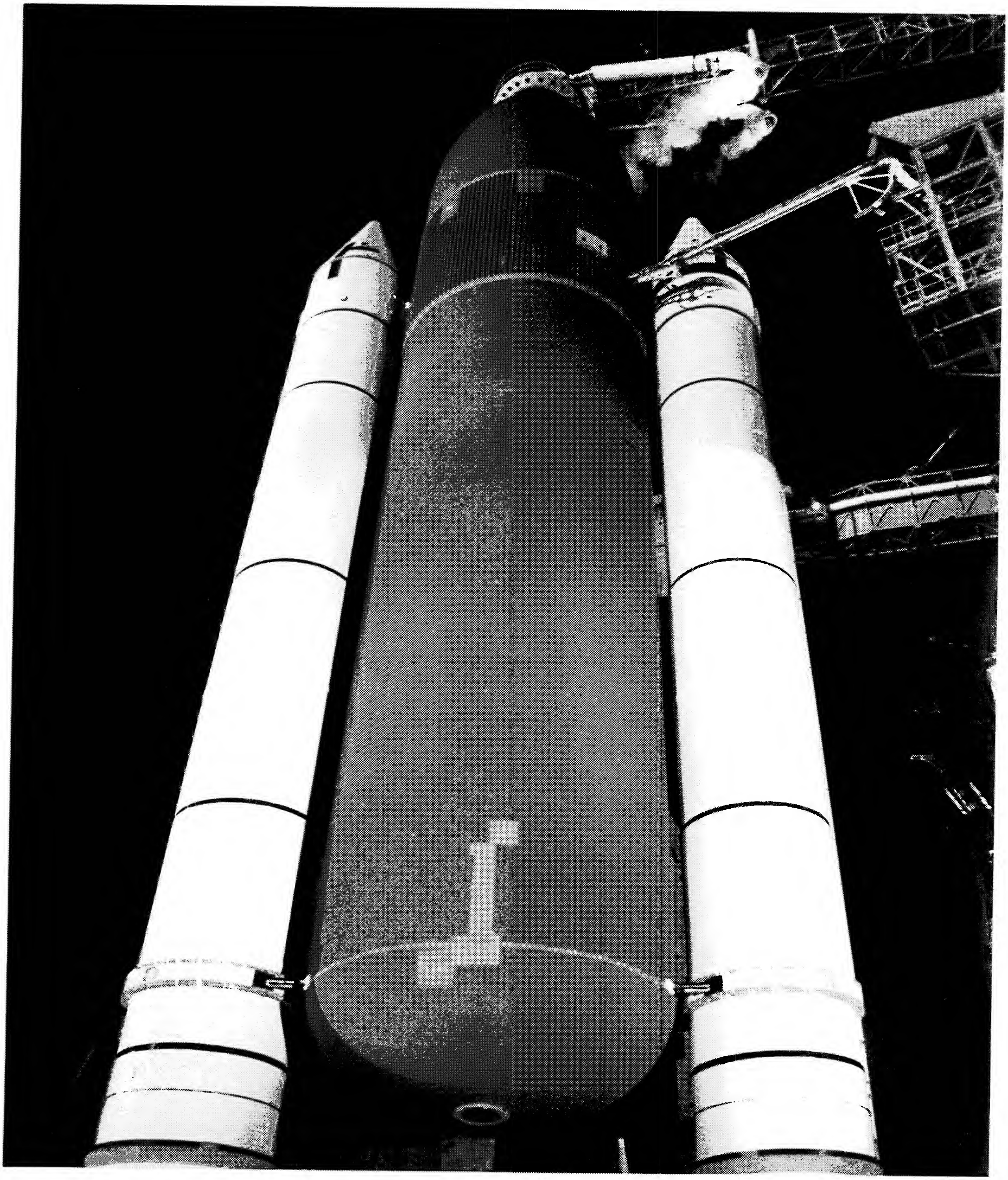
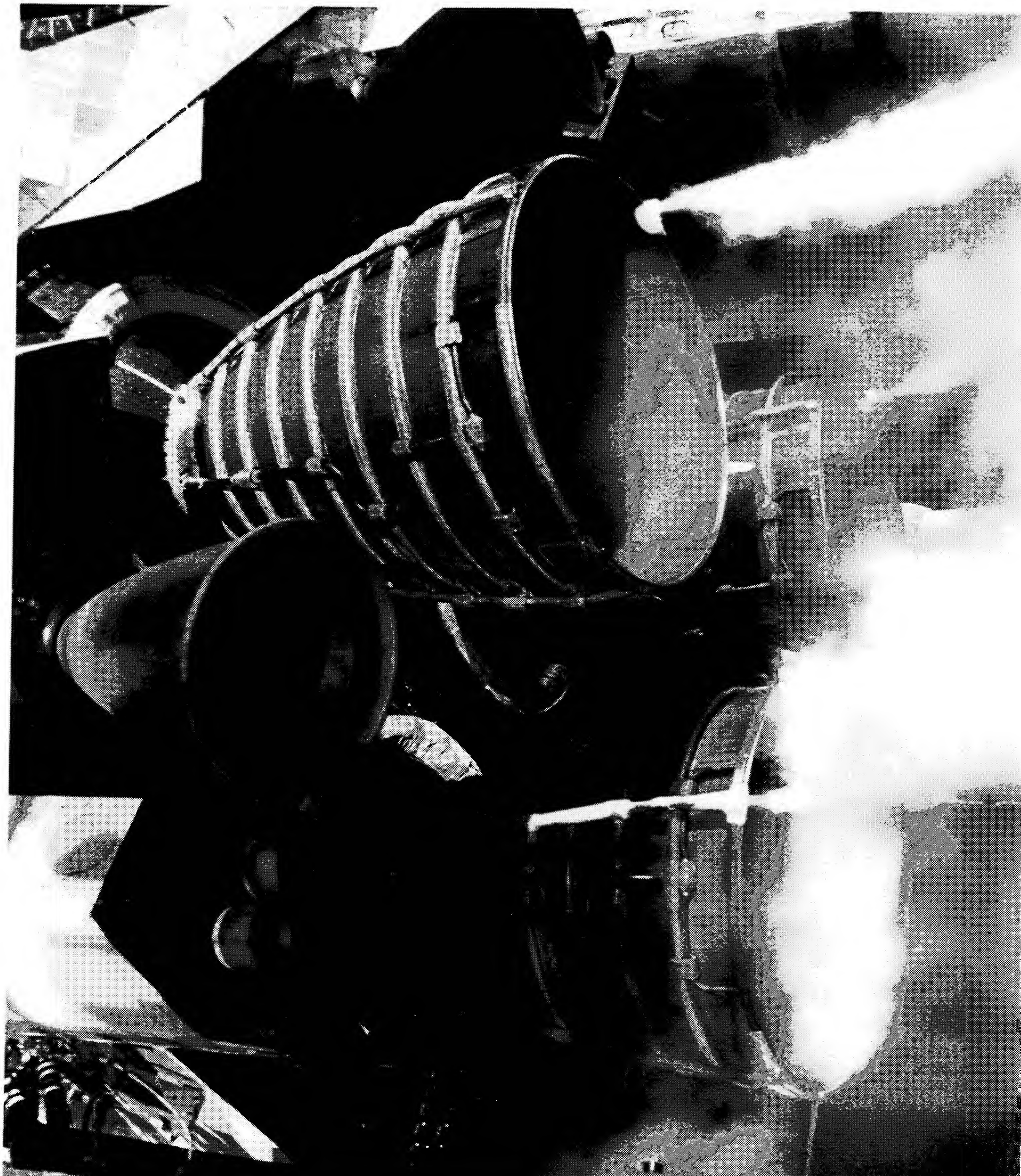


Only condensate was present of the -Z side TPS acreage



Overall view of the SSME's. Note ice/frost on the engine mounted heat shield interfaces and SSME #2 LO2 drain line

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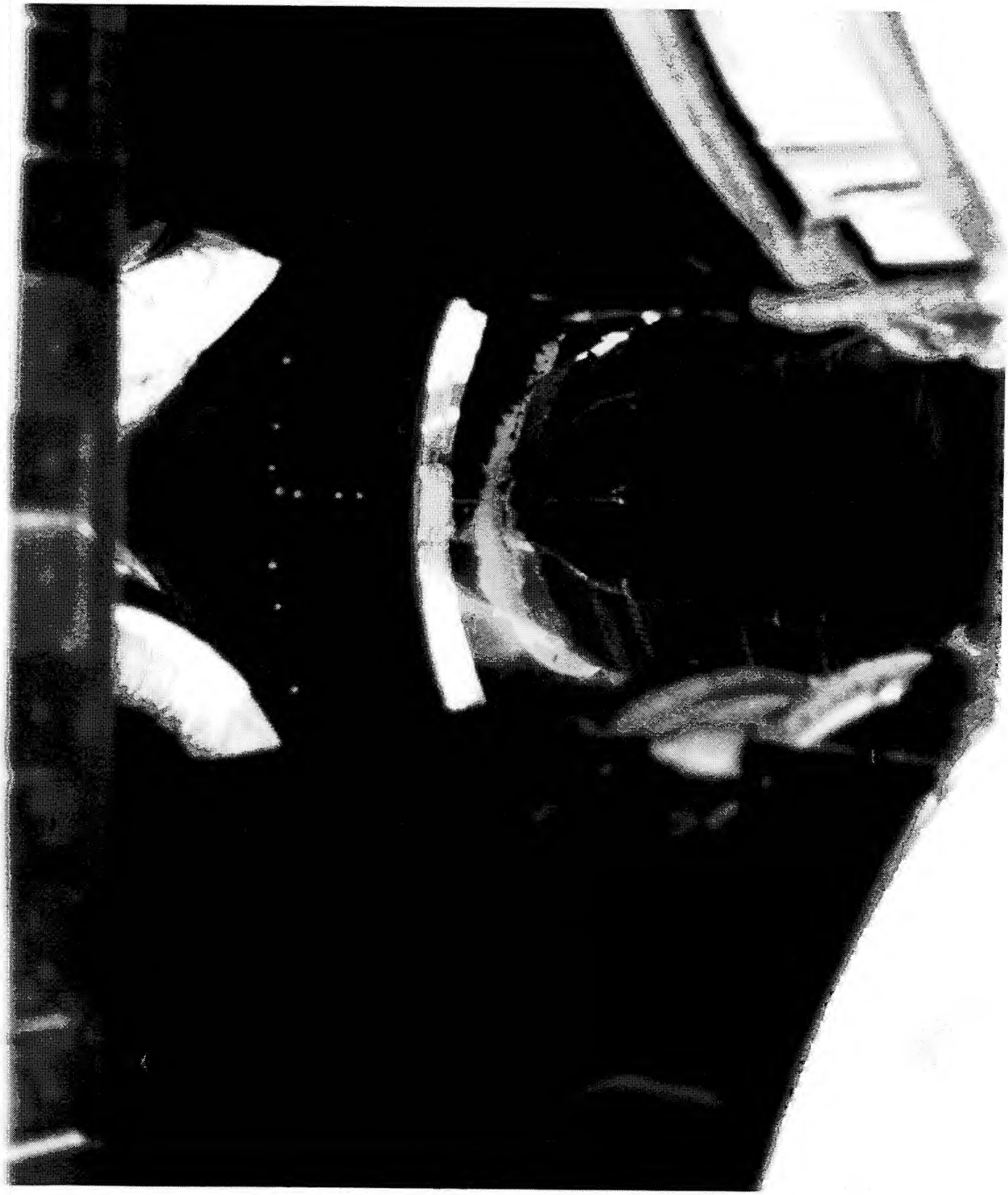
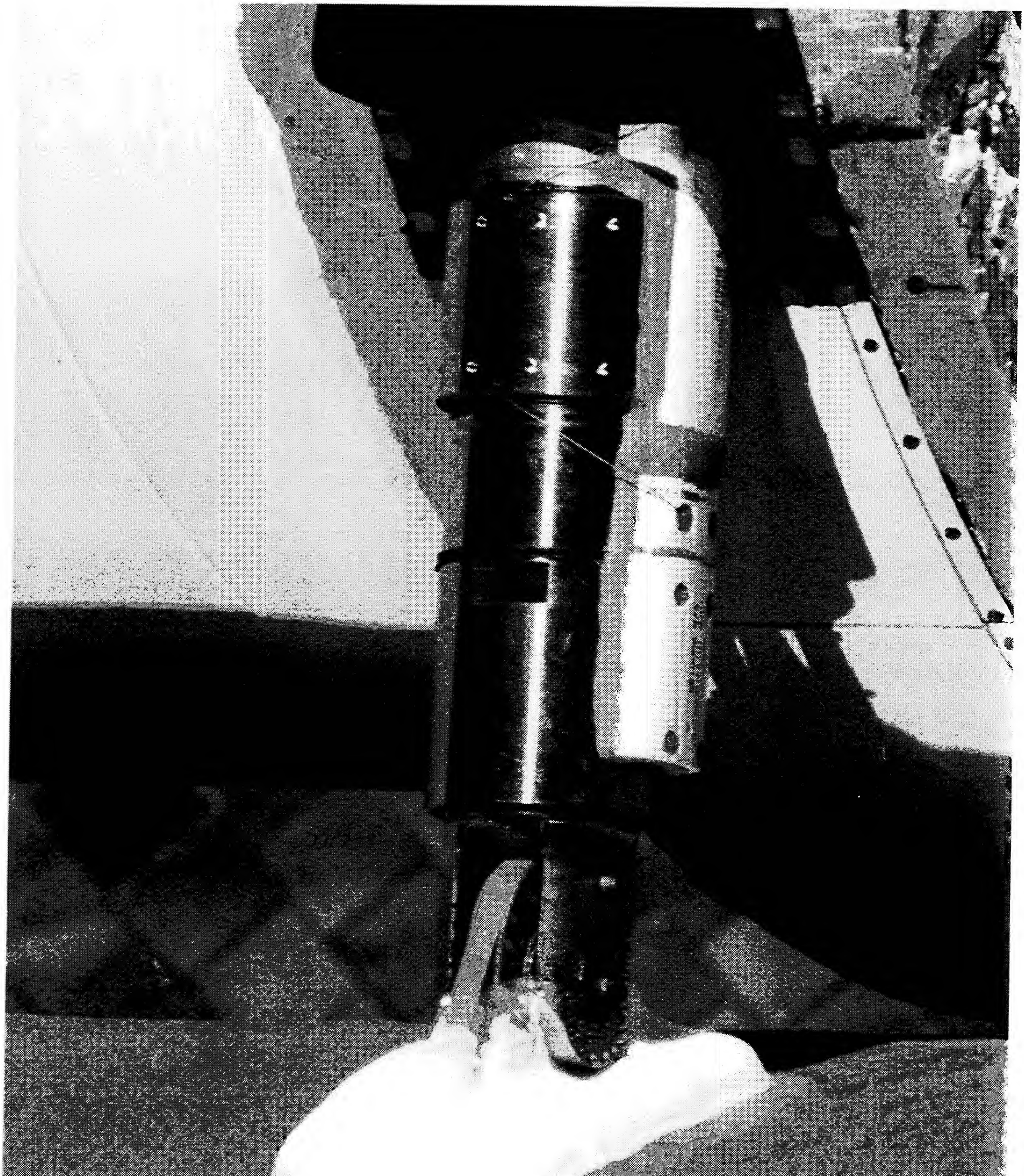


Ice/frost accumulated on the SSME #1 engine mounted heat shield-to-nozzle interface

SSME #2 exhibits condensate on the engine heat shield and frost along the interface. Note frost spot on base heat shield vent.

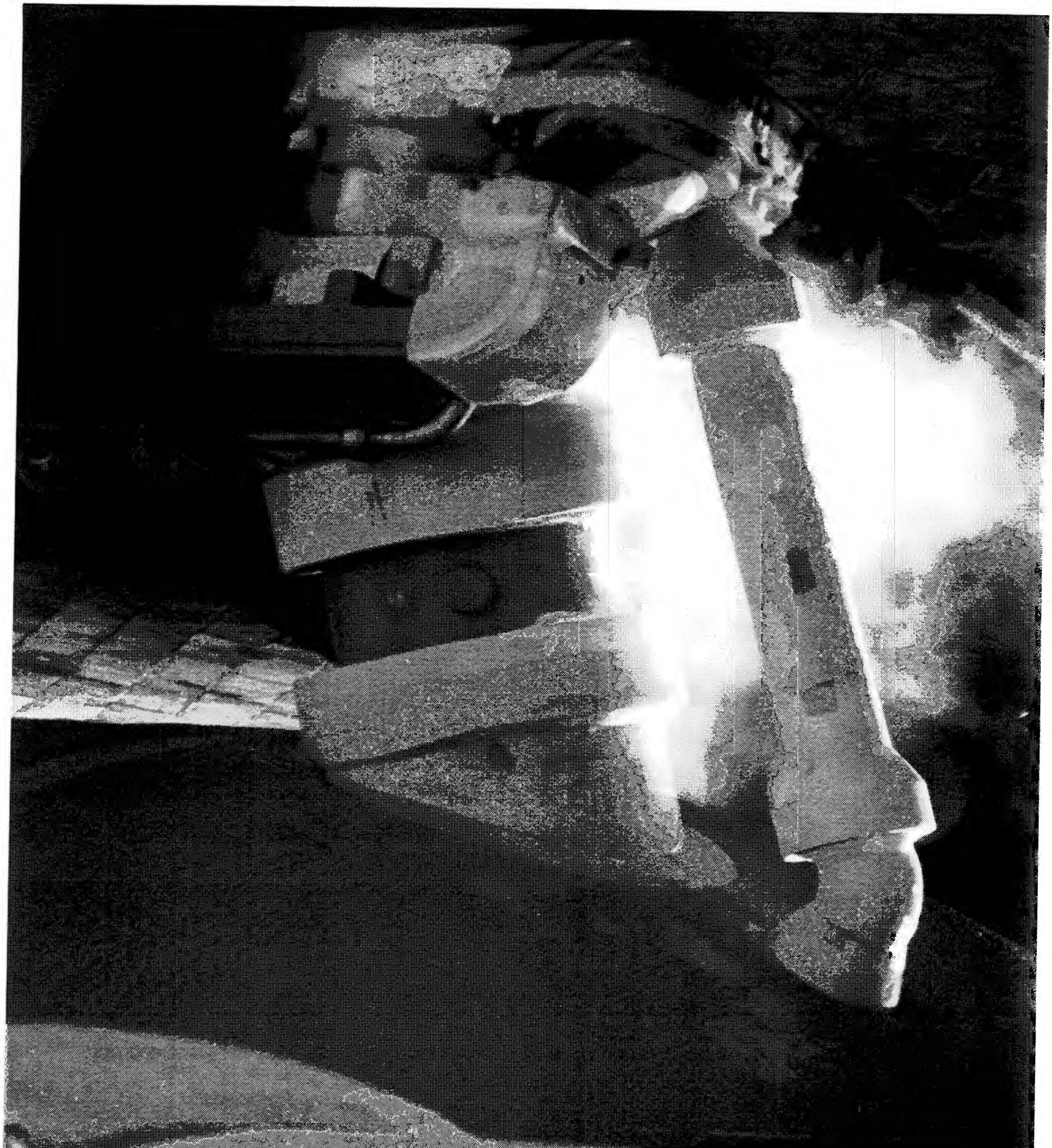
Previous 3-inch diameter repair on LH2 tank aft dome apex begins to protrude due to cryopumping



Although ice/frost covers the EB-7 fitting, only condensate is present on the lower strut clevis

Ice/frost formed on the aft side of the LO2 umbilical, in the LH2 recirculation line bellows, and on all purge vents

Minimal ice/frost has accumulated on the LO2 ET/ORB umbilical baggie and purge vents. Note condensate drops on the cable tray



Ice/frost accumulation on the LH2 umbilical baggie, purge vents and in the feedline/recirc line bellows is heavier than average

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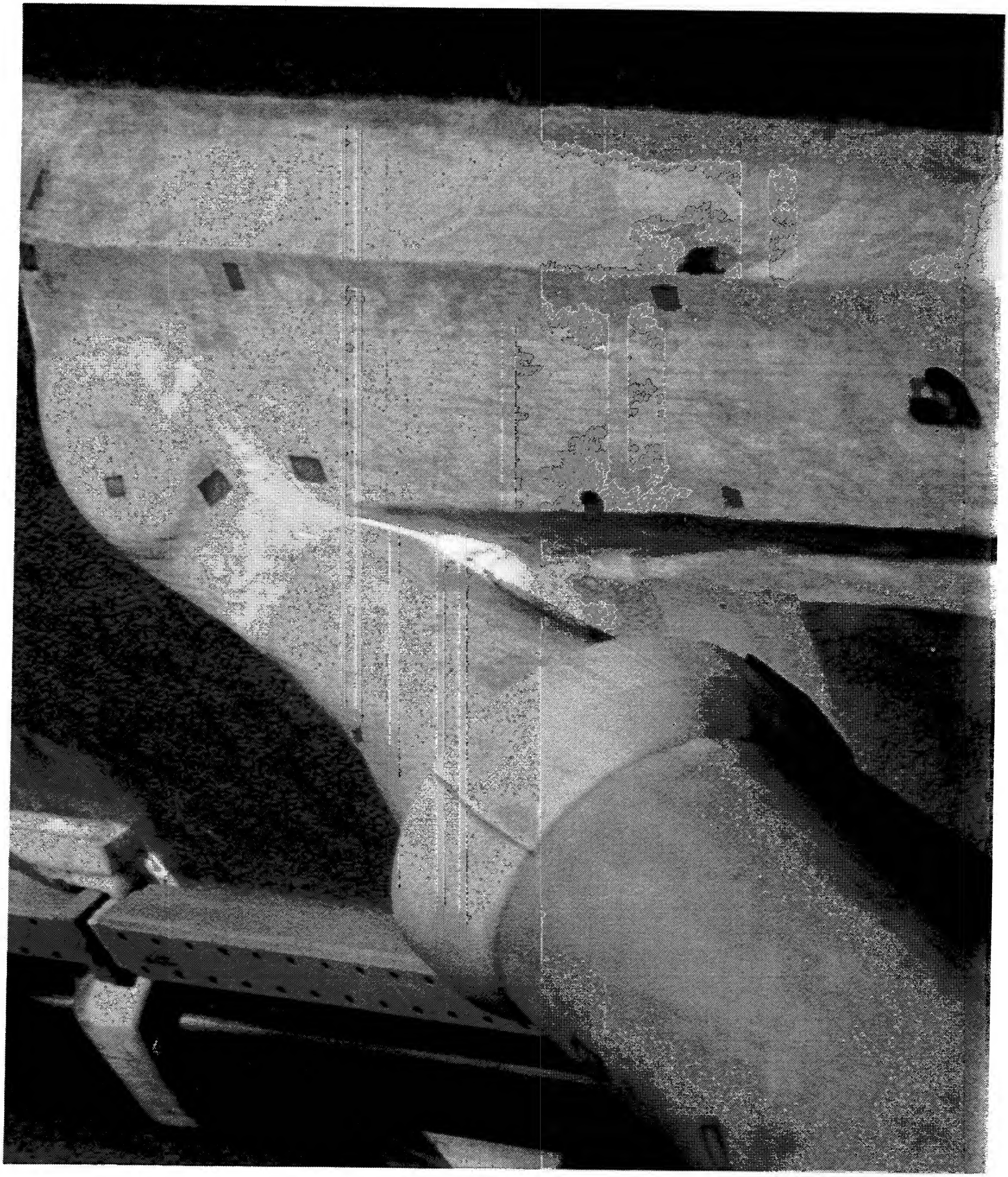

Frost has formed along the cable tray ramp aft side and in a small TPS crack at the longeron-to-thrust strut interface

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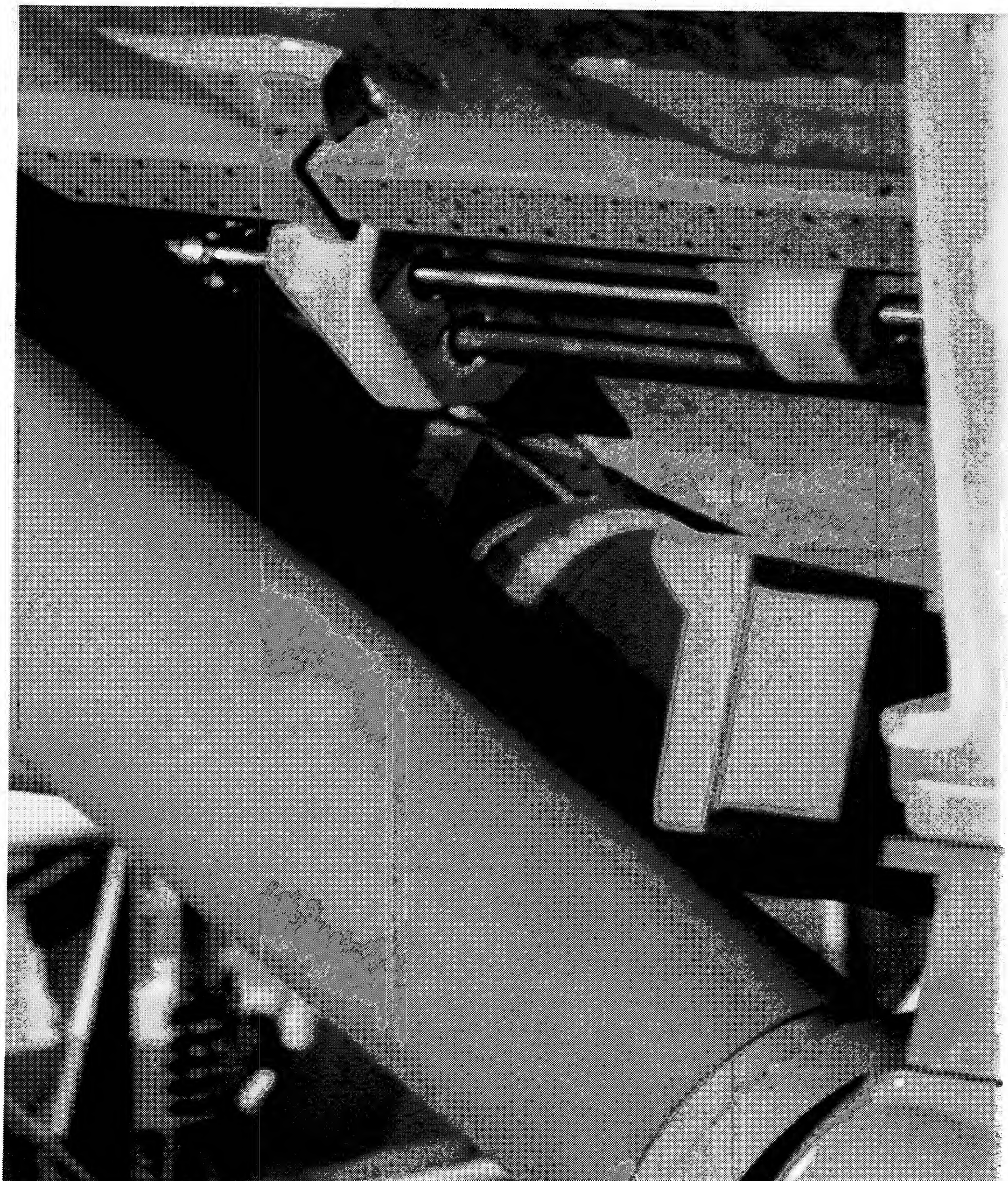
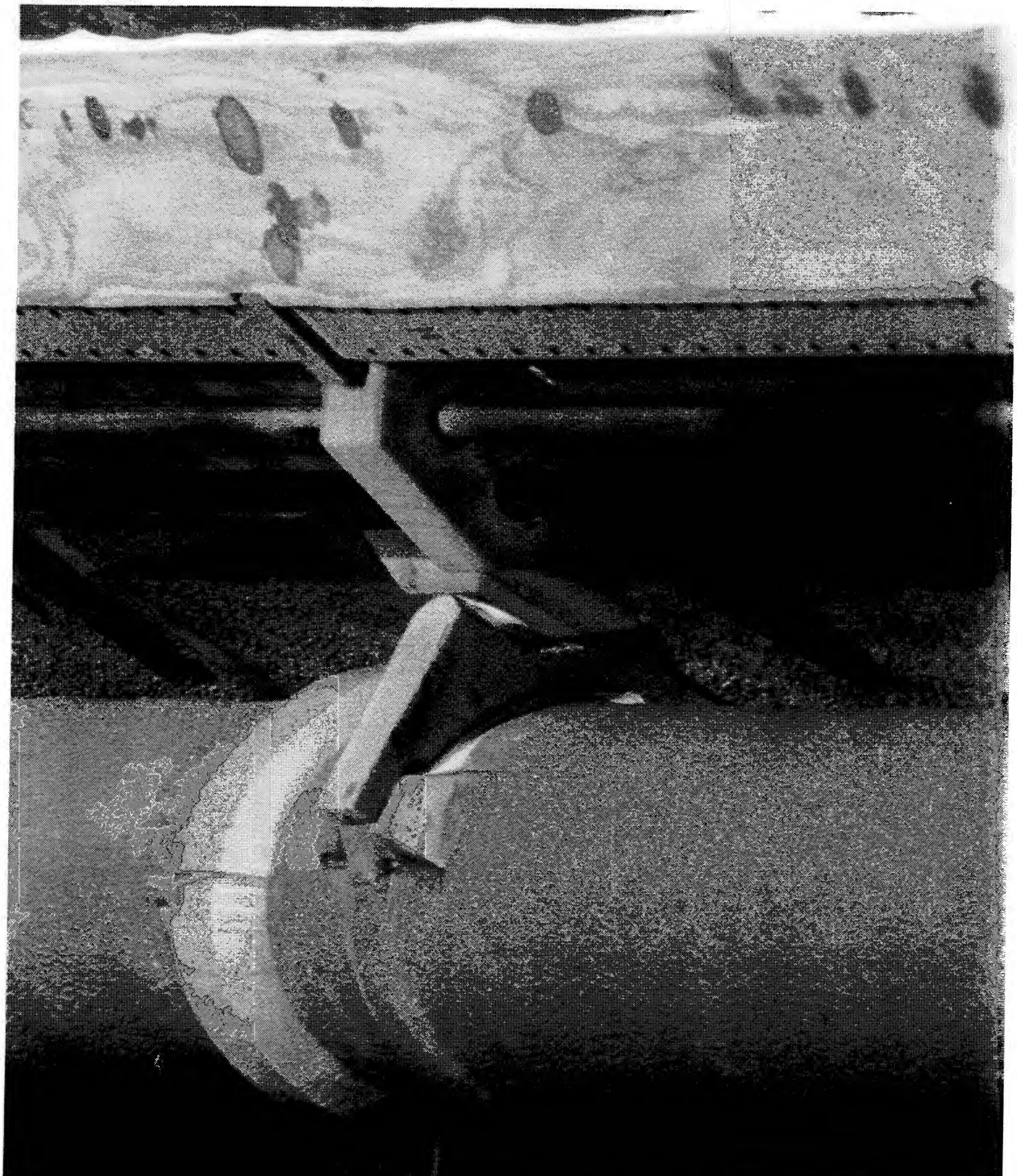
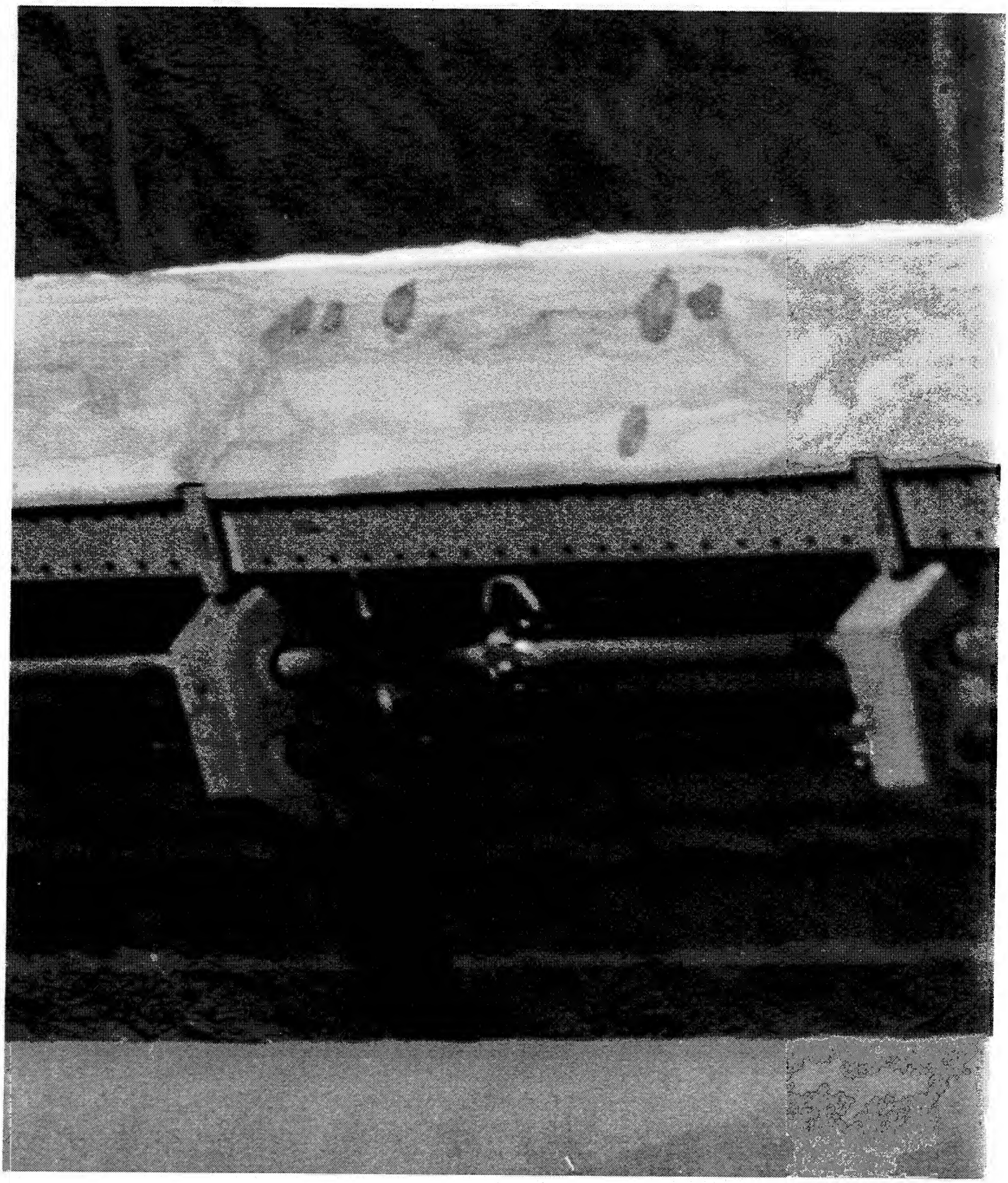


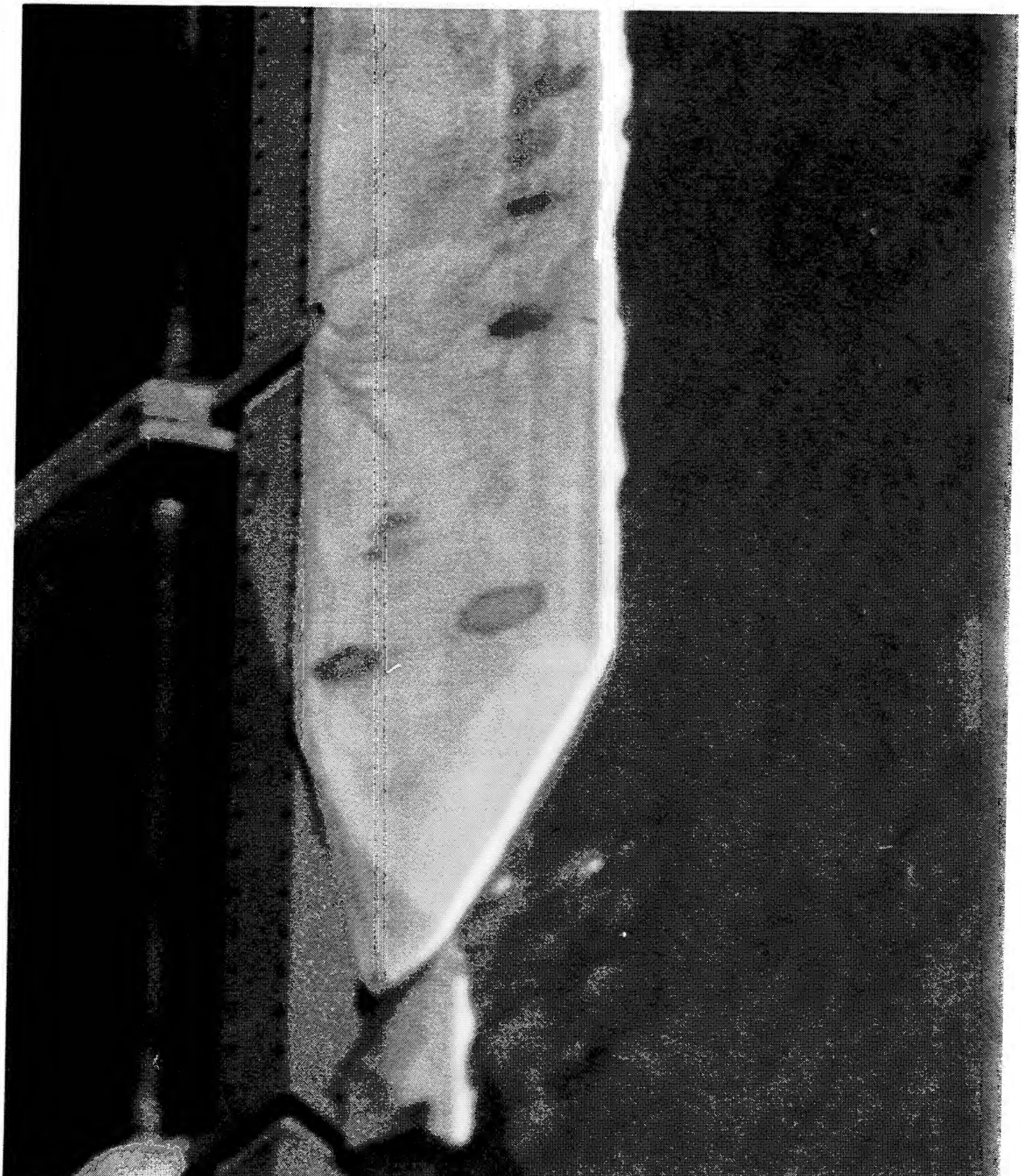
A somewhat heavier-than-usual accumulation of hard ice is visible in the LO2 feedline support bracket and lower bellows



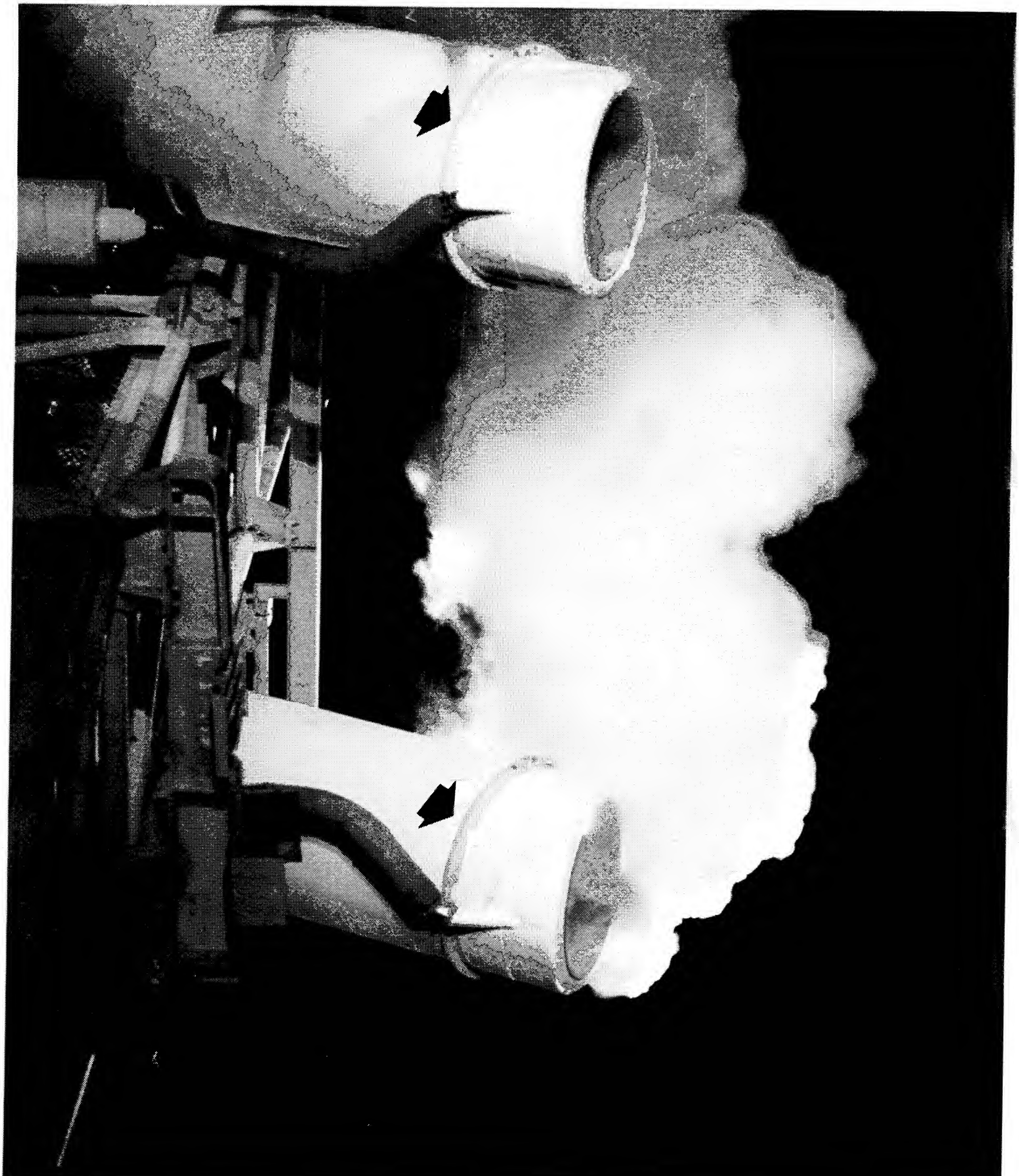
Upper LO2 feedline support brackets were filled with a normal accumulation of ice/frost



Frost outlines the LH2 tank PAL ramp, pressurization line ramps, and a previous 3-inch diameter repair



Frost outlines the LH2 tank PAL ramp, a cable tray ramp, and two small sanded areas from previous acreage repairs



Installation of hydro diverters on the GOX vent ducts after the launch scrub precluded the formation of large icicles

6.0 POST LAUNCH PAD DEBRIS INSPECTION

The post launch inspection of the pad and surrounding area began on 9 January 1990 from launch + 2.5 through 5 hours. The MLP, FSS, pad apron, and acreage areas were inspected. A large piece of white tile screed was found west of the FSS in the box car area and turned in to Operations. The screed was an unrestricted 364 repair on tile V070-197004-069, which was located in the forward, outboard corner on the RH outboard elevon upper surface. The piece of screed measured 4"x3-5/8"x1/2" maximum thickness (the original tile is 1.13 inches thick). No other significant flight hardware or TPS materials were found with the exception of three Q-felt closeout plugs from the Orbiter base heat shield. The usual SRB throat plug material (foam and RTV) was found. Water trough material from the SRB exhaust holes was scattered from the pad apron to the perimeter fence.

SRB holddown post erosion was normal for this launch. South holddown post shim material was intact, but had debonded significantly from the shoe sidewall. The shim on HDP #2 shoe was completely debonded and could be lifted. Two pieces of shim material were found. One appears to be from a previous launch. No conditions indicative of stud hang-up were visible. All of the doghouse blast covers on the north holddown posts were in the closed position, exhibited no apparent damage, and did not appear to be missing any parts. The SRB aft skirt purge lines were in place and slightly damaged. The SRB joint heater umbilicals showed minor damage after separation.

Several pieces of facility debris were found on the pad perimeter. The number of facility items found was typical.

The Orbiter Access Arm (OAA) and Tail Service Masts (TSM) showed signs of slight launch damage. The GOX vent hood windows were broken and the protective foam on top of the hood was partially pulled back. Two pieces of the hood window were later found on the pad. The GH2 vent arm was latched on the fourth tooth of the latching mechanism and showed signs of typical SRB plume heating. The static retract lanyard caused no damage to the GUCP.

All seven emergency egress slidewire baskets were secured on the FSS 195 foot level and sustained no launch damage.

Overall, there was very little damage to the launch pad.

Patrick AFB and MILA radars had been configured again in a mode for increased sensitivity for the purpose of observing any debris falling from the vehicle during ascent. Although the signals were very weak, a total of 29 particles were imaged in the 138 to 320 second time frame. Most of the object are small, relatively, but objects with somewhat larger cross sections are

visible at 151, 169, and 305 seconds. Particles are also visible before SRB separation at 117.5 and 118.5 seconds and would correspond to pieces of SRB propellant slag falling from the plume during tailoff.

The debris inspection continued on 10 January 1990 and was expanded to include areas outside the perimeter fence. Ground teams searched the beach, railroad tracks, and beach access road from the northern KSC boundary to the Titan complex. The NASA helicopter was utilized to cover the water areas around the pad, the beach from the Cape lighthouse to a point 10 miles north of the pad, and the ocean area under the flight path. No flight hardware was found.

During MLP refurbishment, the sandboxes in the holddown posts were opened and the following debris recovered:

HDP #1	1/2" metal fragment, 1" long metal wire
HDP #2	two frangible nut webs
HDP #3	one NSI cartridge, 3/8" metal fragment, 2"x3/16" sliver of rubber
HDP #4	six small (less than 1/2") fragments, one is a piece of frangible nut web
HDP #5	one frangible nut web one piece of NSI cartridge with threads 1-1/2"x1"x1/2" nut fragment 1/4"x1/8" fragment
HDP #6	1/2"x1/2"x1/8" metal fragment
HDP #7	None
HDP #8	3/4"x1/2"x1/8" NSI cartridge fragment with threads 1"x1/2"x1/16" cartridge fragment 4 very small fragments

Post launch pad anomalies are listed in Section 11.1.

Post launch condition of a south SRB holddown post. Note debonded shim on the holddown post shoe.

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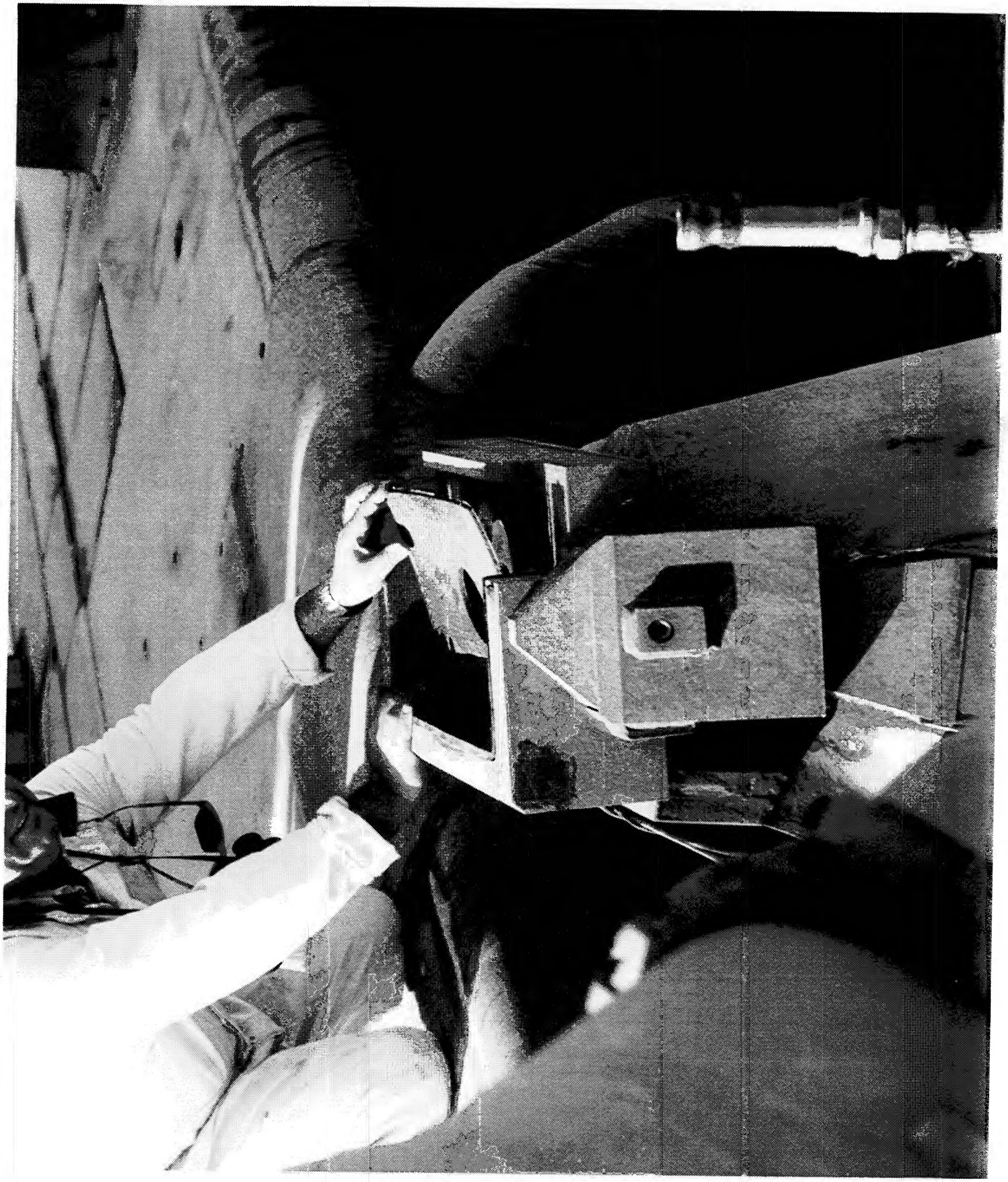
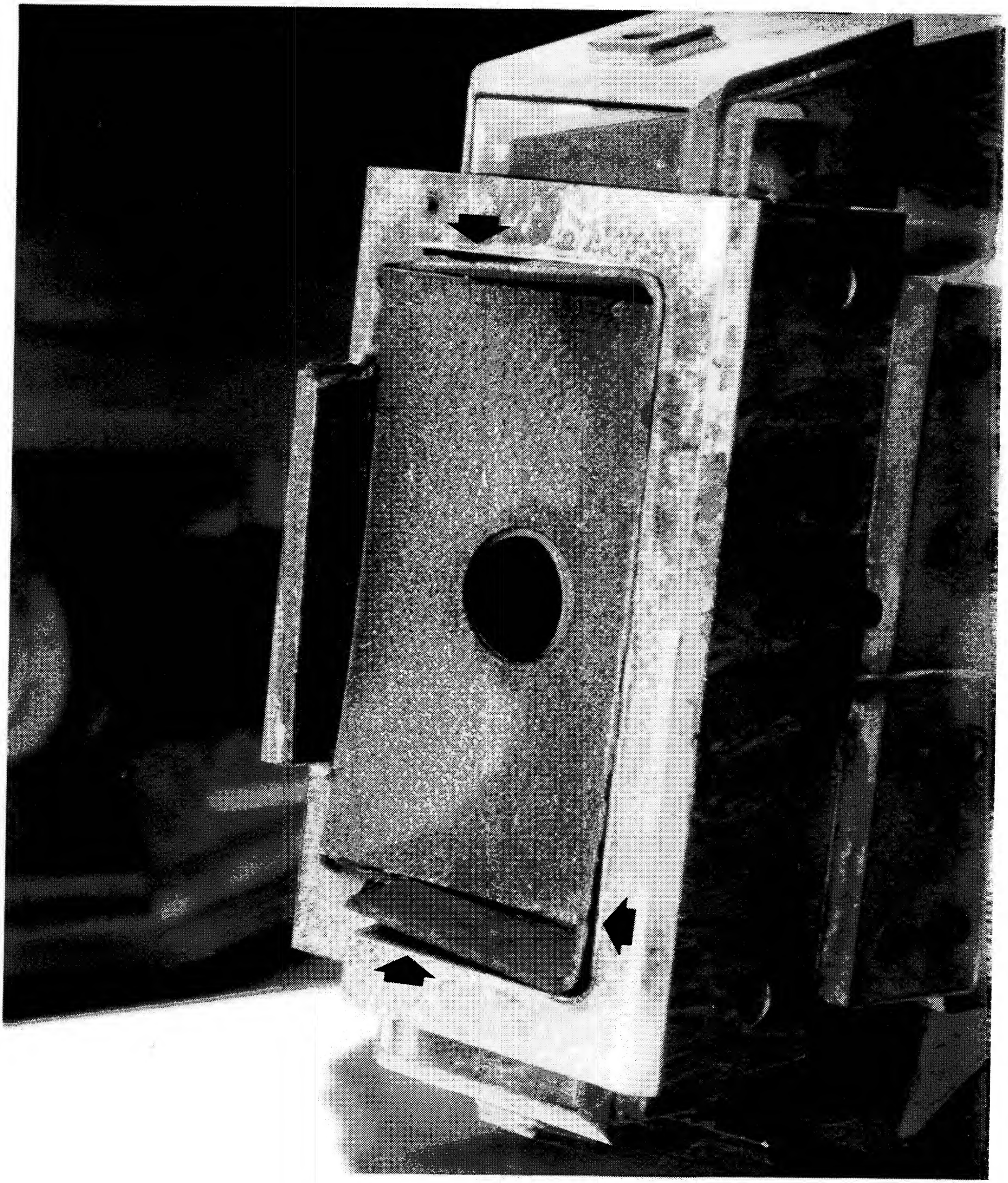
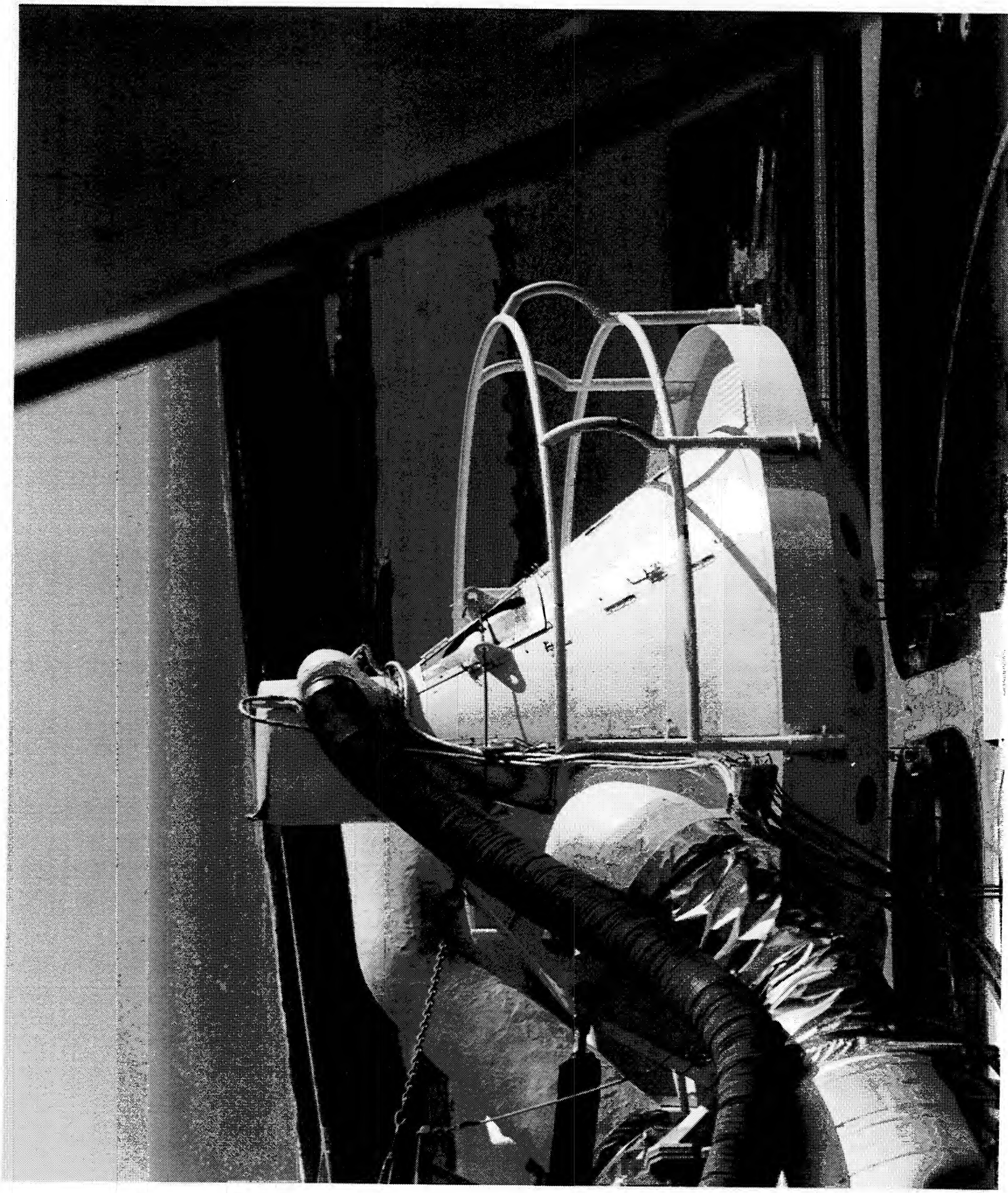
Post launch condition of a north SRB holddown post. All holddown post doghouse blast covers were closed.



Debonded Epon shim on holddown post #2 shoe

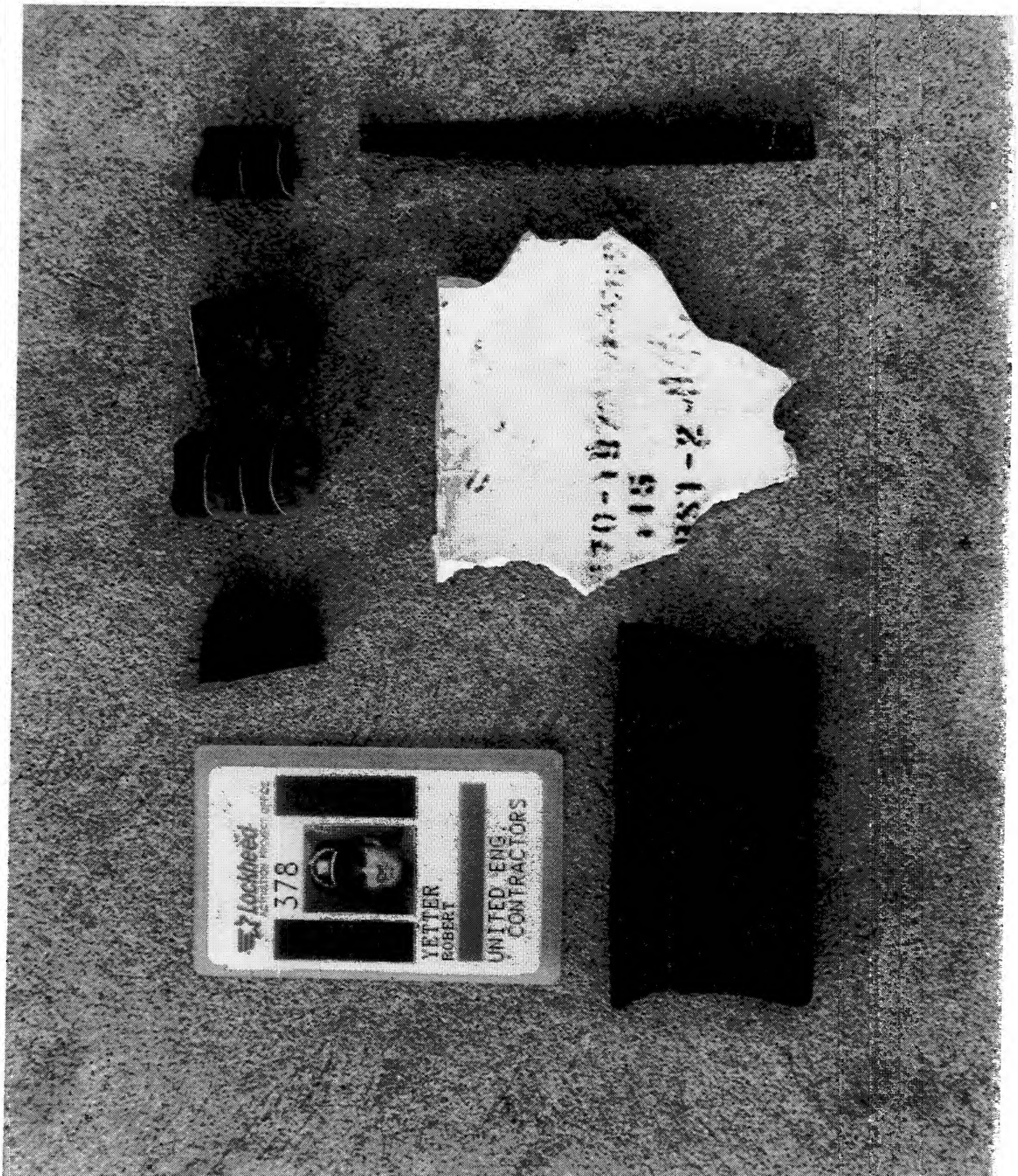


Sidewall shim material was almost completely debonded



The GOX vent hood sustained launch damage in the form of a broken window and torn insulation on the plenum chamber

Typical debris recovered after launch. Note orange GSE tile shim and pieces of window from the GOX vent hood.



Other post launch debris includes RH outboard elevon tile screed, base heat shield Q-felt plugs, and HDP shim material

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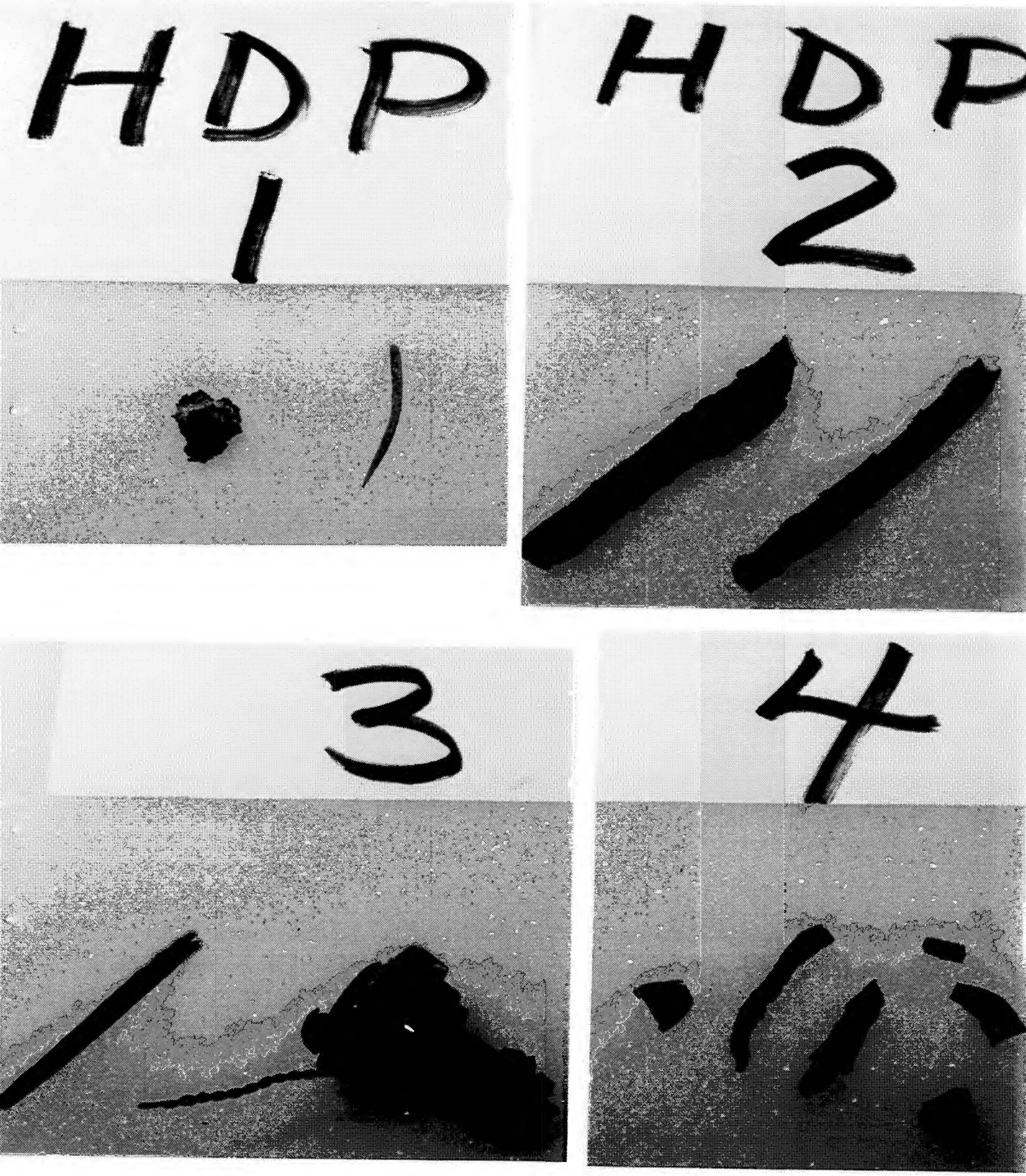

Examination of RH SRB holddown post sandboxes revealed an NSI cartridge and pieces of frangible nut

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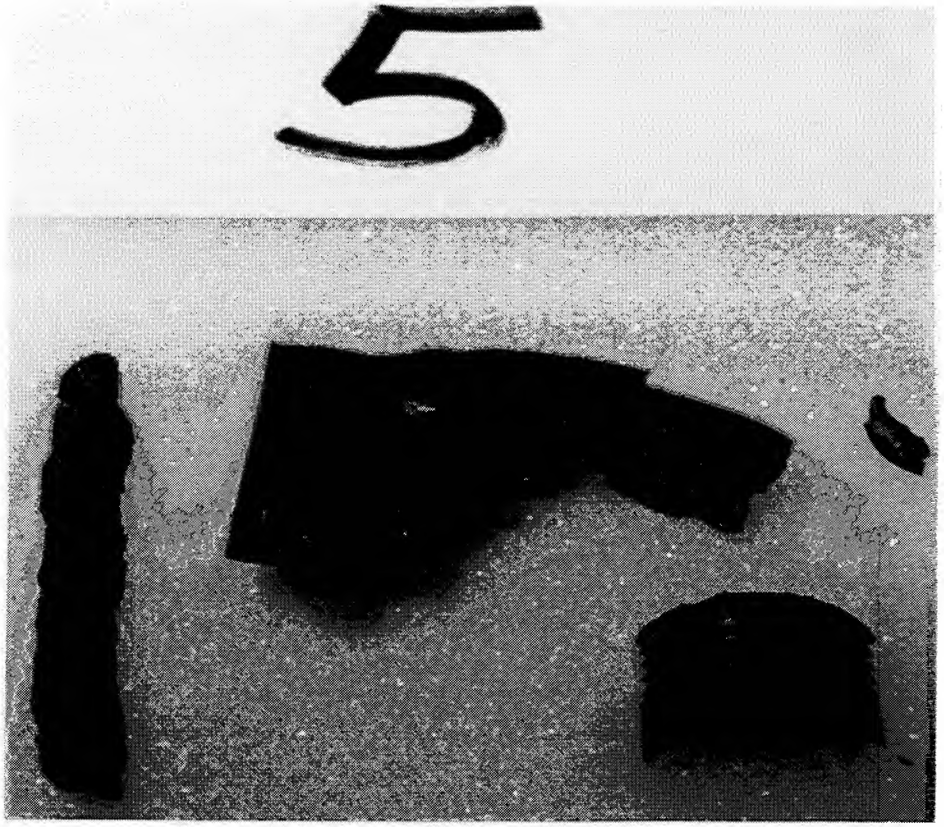

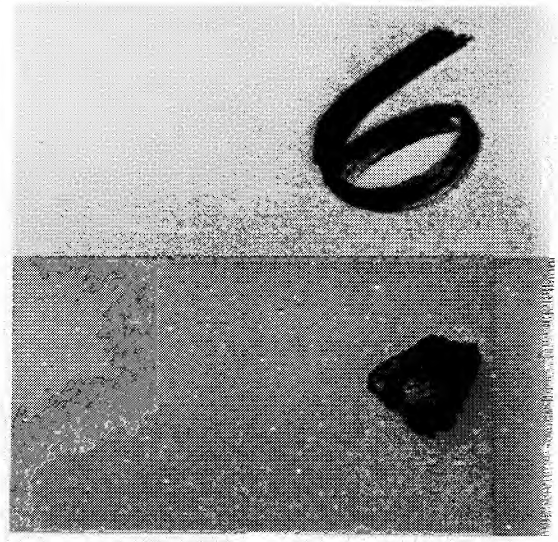

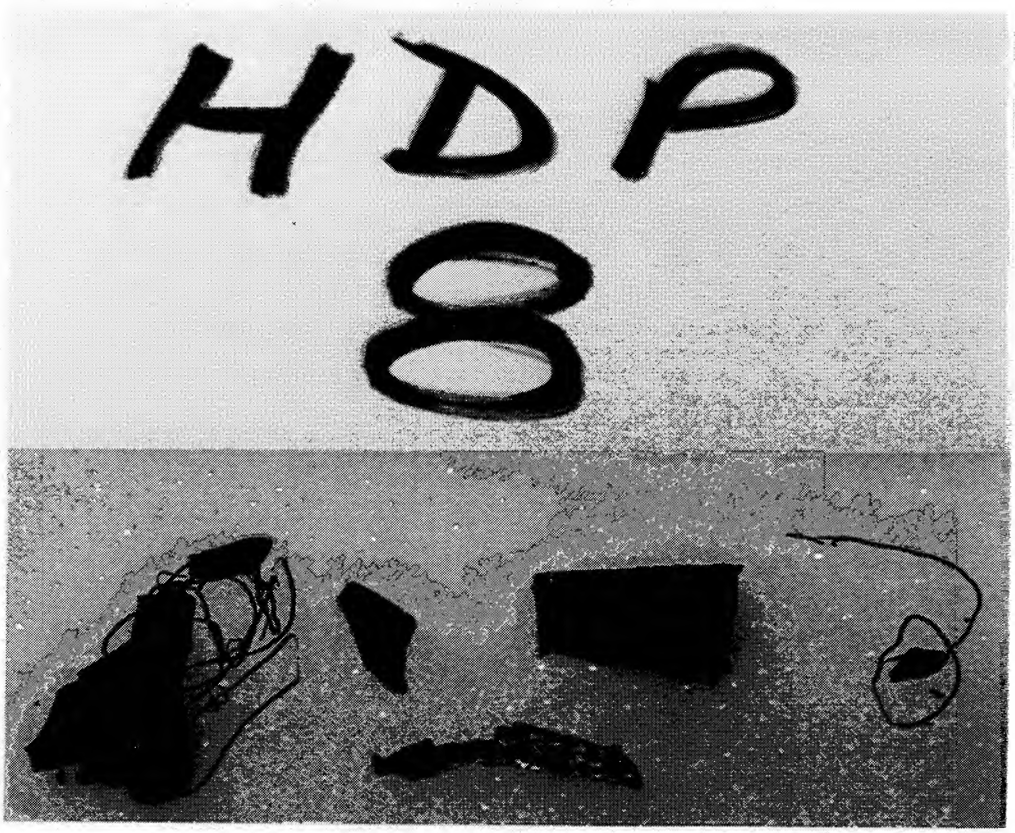

Examination of LH SRB holddown post sandboxes revealed pieces from NSI cartridges and frangible nuts

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6.1 POST LAUNCH CREW COMMENTS ON DEBRIS

From Commander Dan Brandenstein after SRB separation:

Houston - Columbia, on the ascent debris.

Columbia - Houston. We didn't see anything unusual. A couple of small, kind of whitish, looking things going by the side. Also, the forward windscreens received a film from the SRB's at separation. There are a few, what look like skid marks in the film on the windscreens, although we do not see what put the marks there.

OK, we copy that. Thank you, Dan.

7.0 FILM REVIEW SUMMARY/PROBLEM REPORT DISPOSITION

A total of 118 film and video data items, which included 36 videos, 51 16mm films, 25 35mm films, and 6 70mm films were reviewed starting on launch day.

No major vehicle damage or lost flight hardware was observed that would have affected the mission. However, a white tile screed repair fell from the outboard forward corner of the RH outboard elevon upper surface just before the vehicle completed the roll maneuver (E-52, 57, 210, 207, 211, 211, 213, 220, 222, 223, TV-4, ET-207, ET-212). The screed was later found on the pad west of the FSS.

An irregular shaped, translucent piece of ice, entering the FOV from above, fell vertically and bounced on the MLP deck sloped ramp without shattering (frame 192 or GMT 12:34:51.433) before falling into the SRB HDP haunch. The object is not symmetric about any axis and is not a metallic washer. Swing arms were already retracted against the FSS and SSME ignition had not yet occurred. However, water deluge on the FSS was activated at T-16 seconds and may have provided enough water flow with the westerly winds to dislodge the ice from the vehicle. Some of that water spray was visible passing by the RH SRB aft BSM's. Later, an ice particle from the ET/ORB LO2 umbilical fell to the deck and bounced without shattering in a similar manner.

Hydrogen 'lead' was visible exiting the SSME #1 nozzle during the ignition sequence (19, 20, 76, 77, OTV 71). Red streaks in the SSME exhaust plume were caused by pieces of RCS paper covers falling into the plume (E-2).

SSME ignition acoustics and vibration caused small pieces of tile surface coating material to shake loose from the base heat shield and the aft side of the RH RCS stinger (E-17, 18, 20). A heavy shower of ice/frost particles from the ET/ORB LH2 and LO2 umbilicals fell past the body flap during SSME ignition, but no tile damage was visible (E-5, 6, 25, 26, 31, OTV 9, OTV 63).

An orange GSE tile shim, approximately 4"x1" in size, fell from the RH wing lower surface near the leading edge RCC panels. About 12 particles of white tile surface coating material were shaken loose by SSME ignition from the RH elevon upper surfaces (E-6, 25).

Frangible links between the DCS plungers and the holddown post studs were omitted for this flight in an attempt to eliminate stud hang-ups. However, this change caused a considerable amount of debris to fall from the vehicle during liftoff. One NSI-size object fell from HDP #3 aft skirt stud hole in E-10, two large and 11 smaller pieces of frangible nut and NSI cartridge from HDP #5 stud hole (EX4, E-12), one object from HDP #7 stud hole (E-11), and two objects from the HDP #8 stud hole (E-14, 28). The shoe shim on HDP #2 debonded, was

partially lifted by the aft skirt foot through 8 inches of vehicle rise, and then fell back onto the HDP shoe (E-8). Closure of the HDP doghouse blast covers was nominal (Figure 12).

There were no major facility anomalies. No swing arms or other pad structures contacted the vehicle during liftoff. The GH2 vent line latched properly, but there was excessive slack in the static lanyard during retraction. The GUCP was not damaged by the lanyard (E-41, 50).

Many film and video items recorded various amounts of flying debris on the pad after the vehicle cleared the tower. This debris is SRB throat plug material and shredded sound suppression water troughs - an expected occurrence.

Movement of the Orbiter body flap during ascent was generally not visible due to time of launch, partial cloud cover, and vehicle trajectory. Although the body flap was visible for short periods during liftoff and roll maneuver, no significant movement was apparent. Sensors mounted to the body flap for this flight measured an amplitude of 3.0 inches peak to peak at the sensor location. Extrapolation of the movement to the trailing edge of the body flap gave an amplitude of 4.7 inches. Measured frequencies compared closely with predicted and previous flight data.

Seven flashes were visible in the SSME plume during ascent. Most, but not all, of the flashes could be explained by debris, such as RCS paper covers, entering the plume. However, one particularly large flash occurred at GMT 12:35:43 (E-204, 207, 213, 218, 220, 222, 223, TV-4). Plume recirculation, a normal occurrence, was visible in E-204, 206, TV-18, ET-206.

Numerous pieces of debris from the vehicle were visible during ascent. Most have been identified as ice/frost particles from the ET/ORB umbilicals and RCS paper covers from the Orbiter (E-52, 54, 57, 58, 61). The particles falling from the vehicle after Max Q are either pieces of SRB propellant/inhibitor or SRB aft skirt instafoam (E-207, 223, TV-5). More than 100 chunks of SRB propellant slag, some of which appear very large due to the burning 'blooming' effect, were visible in the SRB plumes prior to and just after separation from the External Tank (E-201, 205, 207, 211, 223, TV-5, ET-204, ET-207).

One 35mm and two 16mm cameras in the ET/ORB umbilicals recorded SRB and ET separation. No anomalies were visible on the ogive or nosecone. The acreage of the intertank was intact except for five large divots in the area of the bipods (Figure 13). Two divots measuring 12-14 inches in diameter were located between the bipods and just above the intertank-to-LH2 tank flange. A third divot 14 inches in diameter was centered between the bipod ramps and extended into the intertank-to-LH2 tank flange. The largest divot, measuring 28 inches wide, surrounded the

Figure 12: Dog House Closure Data

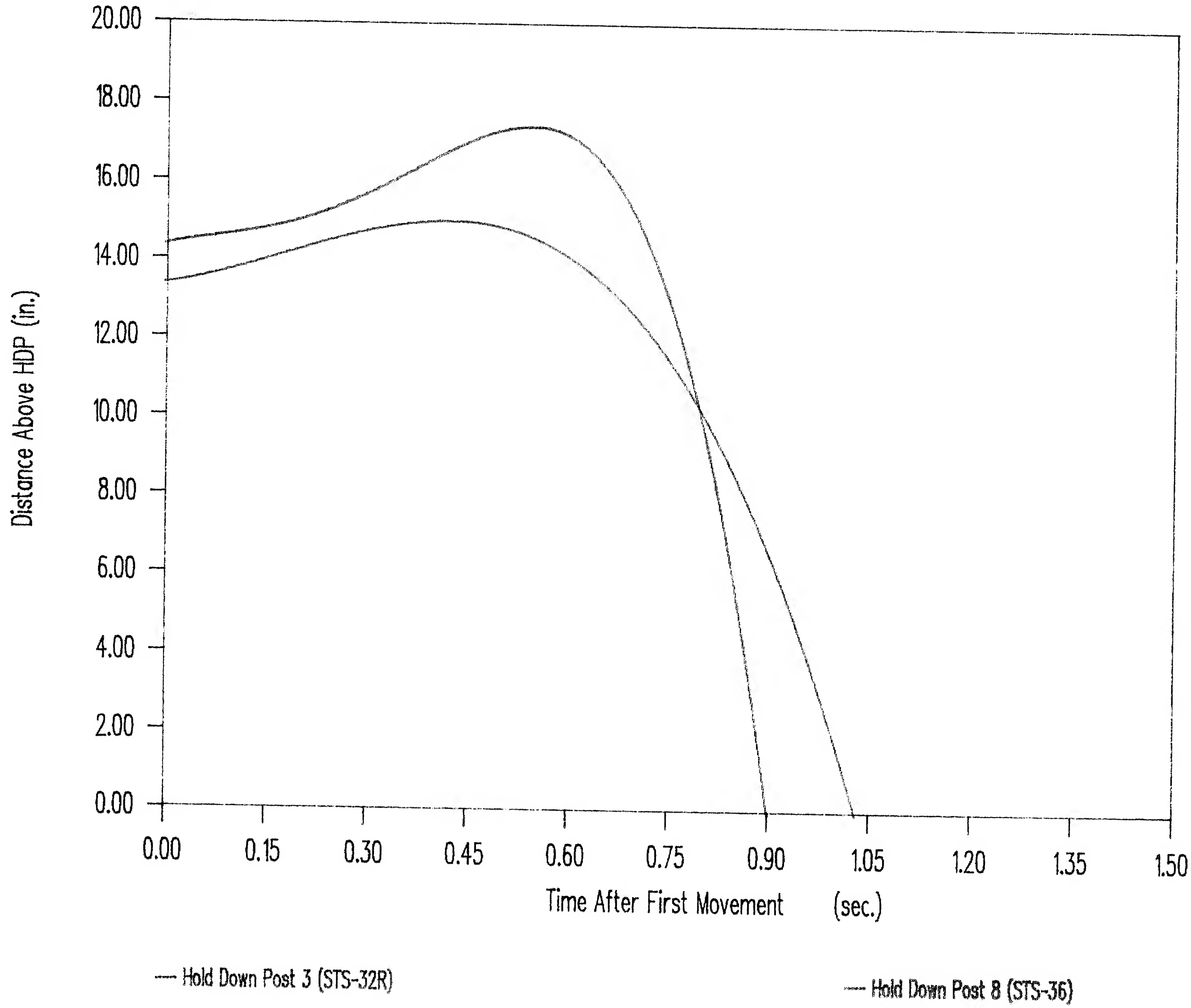
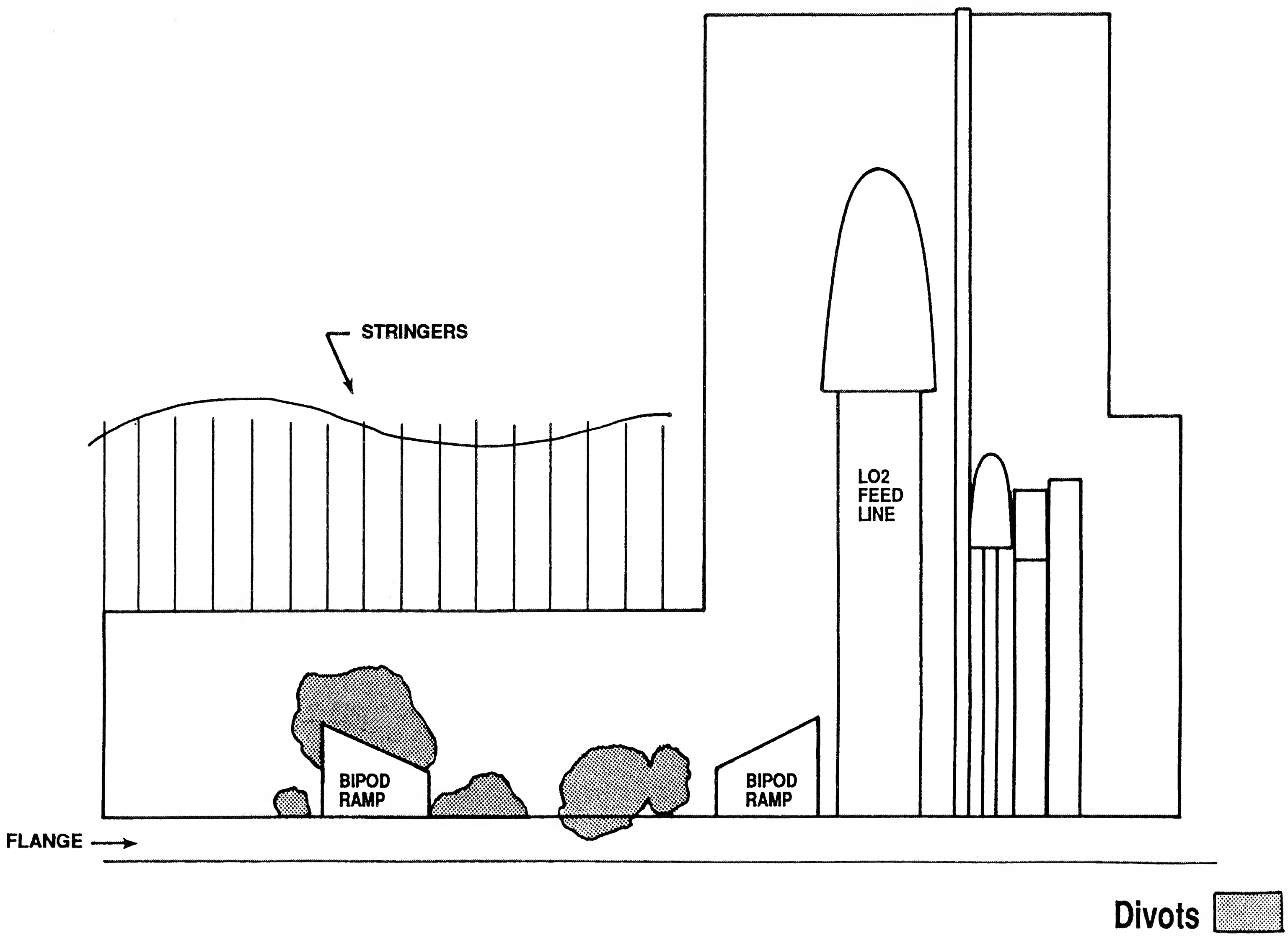


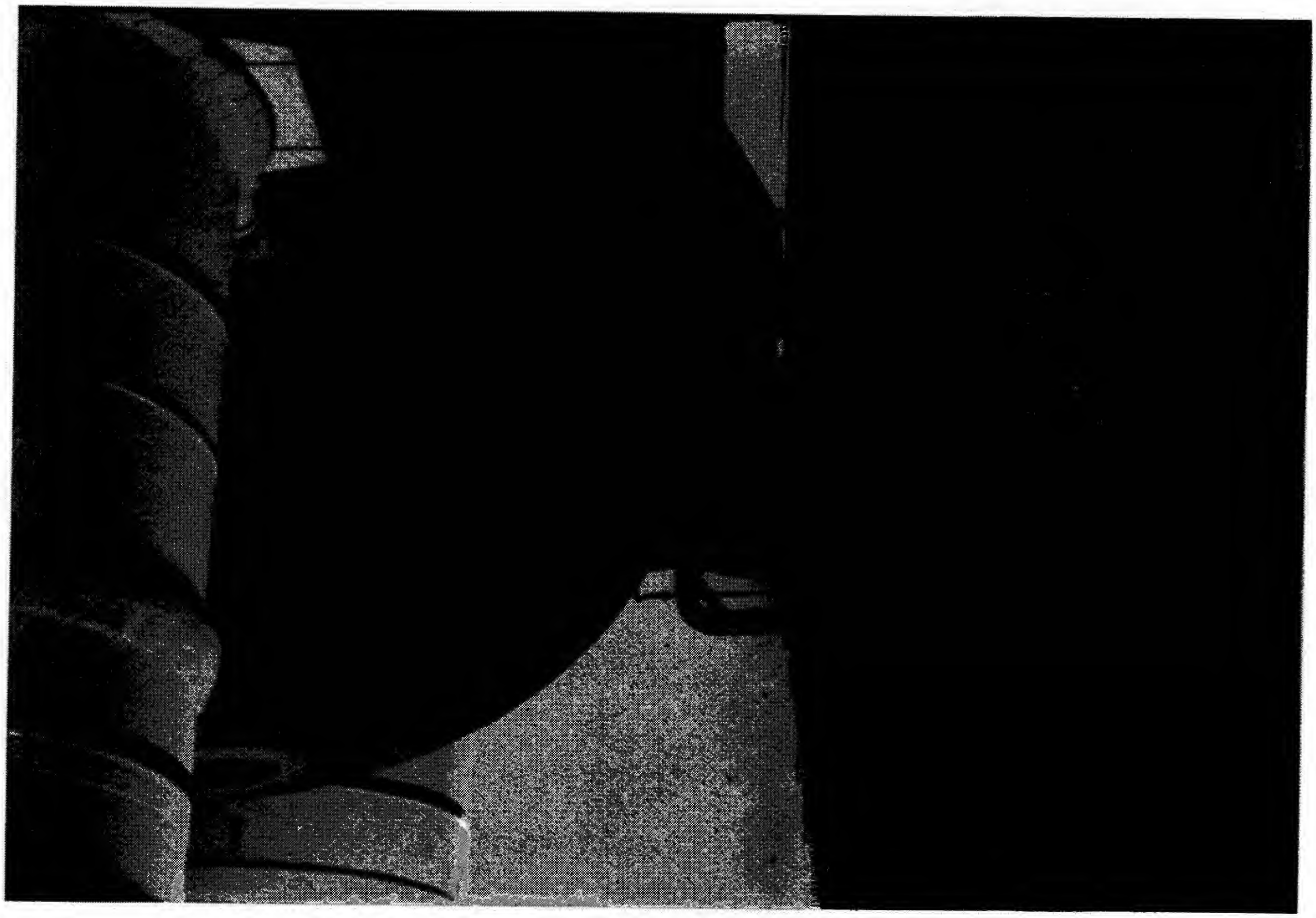
FIGURE 13. **STS-32R IN-FLIGHT ANOMALY (STS-32-T-1)**
Missing Intertank TPS Shown on Post Separation Photos



forward part of the LH bipod ramp. Stringers were visible in the divots indicating a depth greater than the isochem line. A fifth divot measuring 6 inches in diameter was located outboard of the LH bipod ramp and just above the LH2 tank splice. The LH2 tank acreage was in good condition with the exception of 2 divots, one of which was a repair, in the spray abort areas. Four large pieces of ET TPS appeared from behind the umbilical cable tray or fell aft into the field of view. These foam pieces were the divots from the intertank area. The top of the LH2 umbilical was damaged and covered with frozen hydrogen. The LO2 umbilical was in good condition with the exception of ice or a thin layer of TPS peeled back on top of the umbilical.

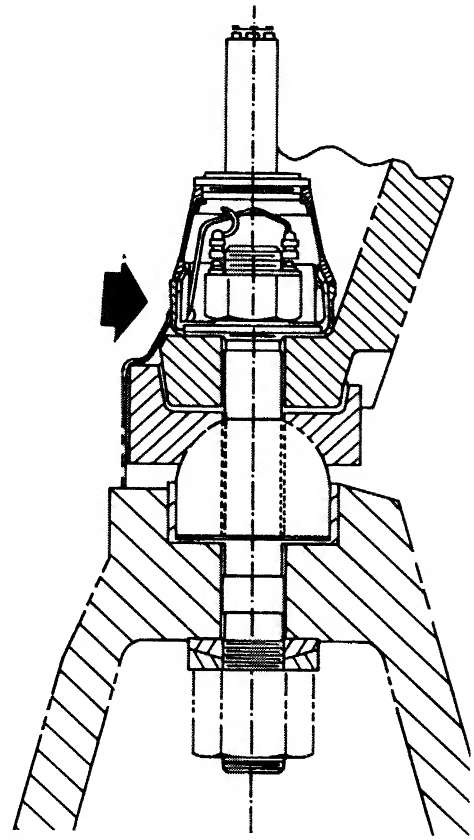
No PR's or IPR's were generated as a result of the film and video data review. However, the Post Launch Anomalies observed in the Film Review and IFA candidates were presented to the Mission Management Team, Shuttle managers, and vehicle systems engineers. These anomalies are listed in Section 11.2.

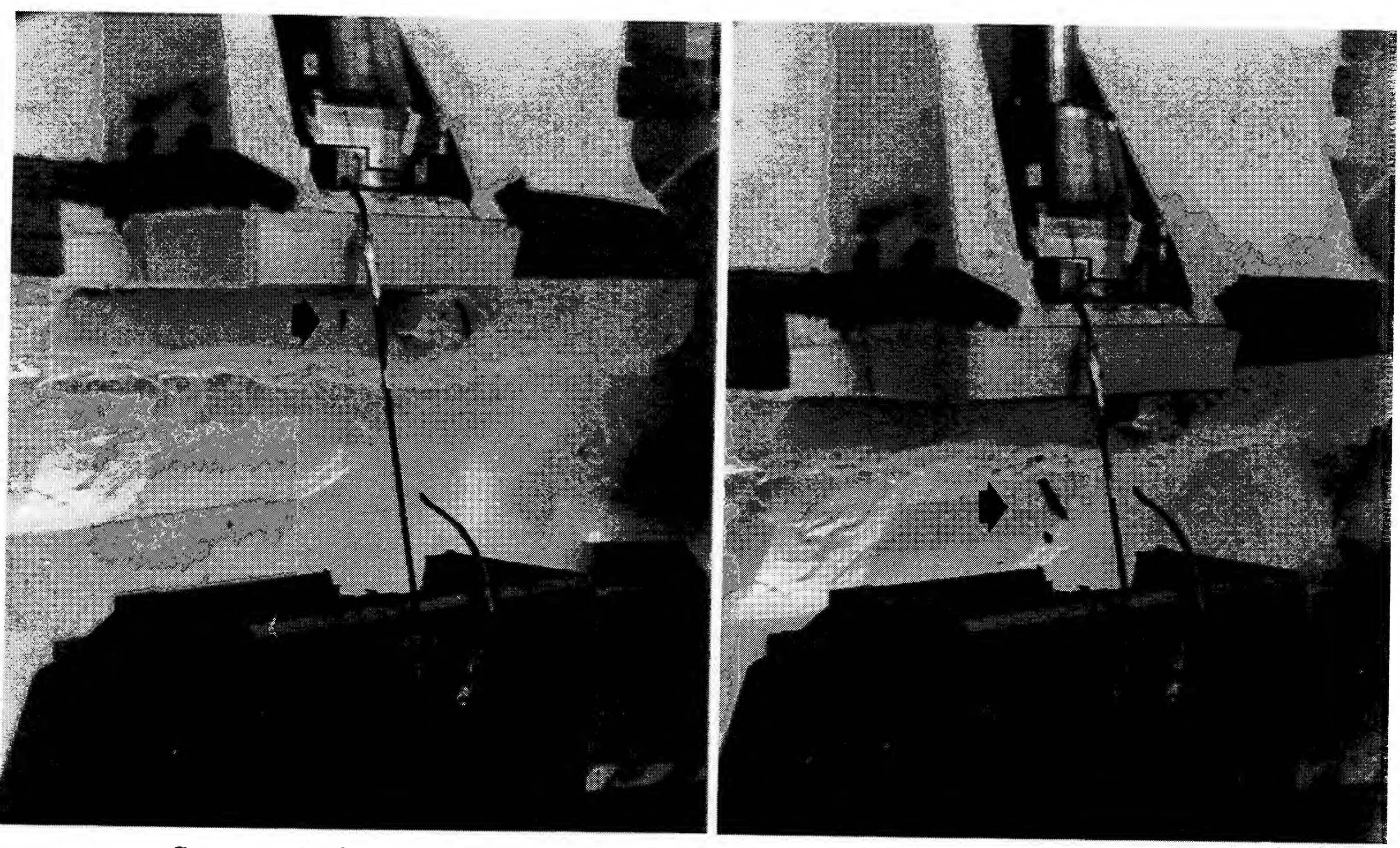
Hydrogen 'lead' exits SSME #1 nozzle just prior to ignition



SSME ignition acoustics and vibration cause ice/frost particles to fall from the ET/ORB umbilicals

Debonded holddown post #2 shoe shim material is lifted briefly by RH SRB aft skirt, then falls back onto the HDP shoe





Camera EX4 recorded numerous pieces of frangible nut and NSI cartridge falling from HDP #5 aft skirt stud hole/DCS

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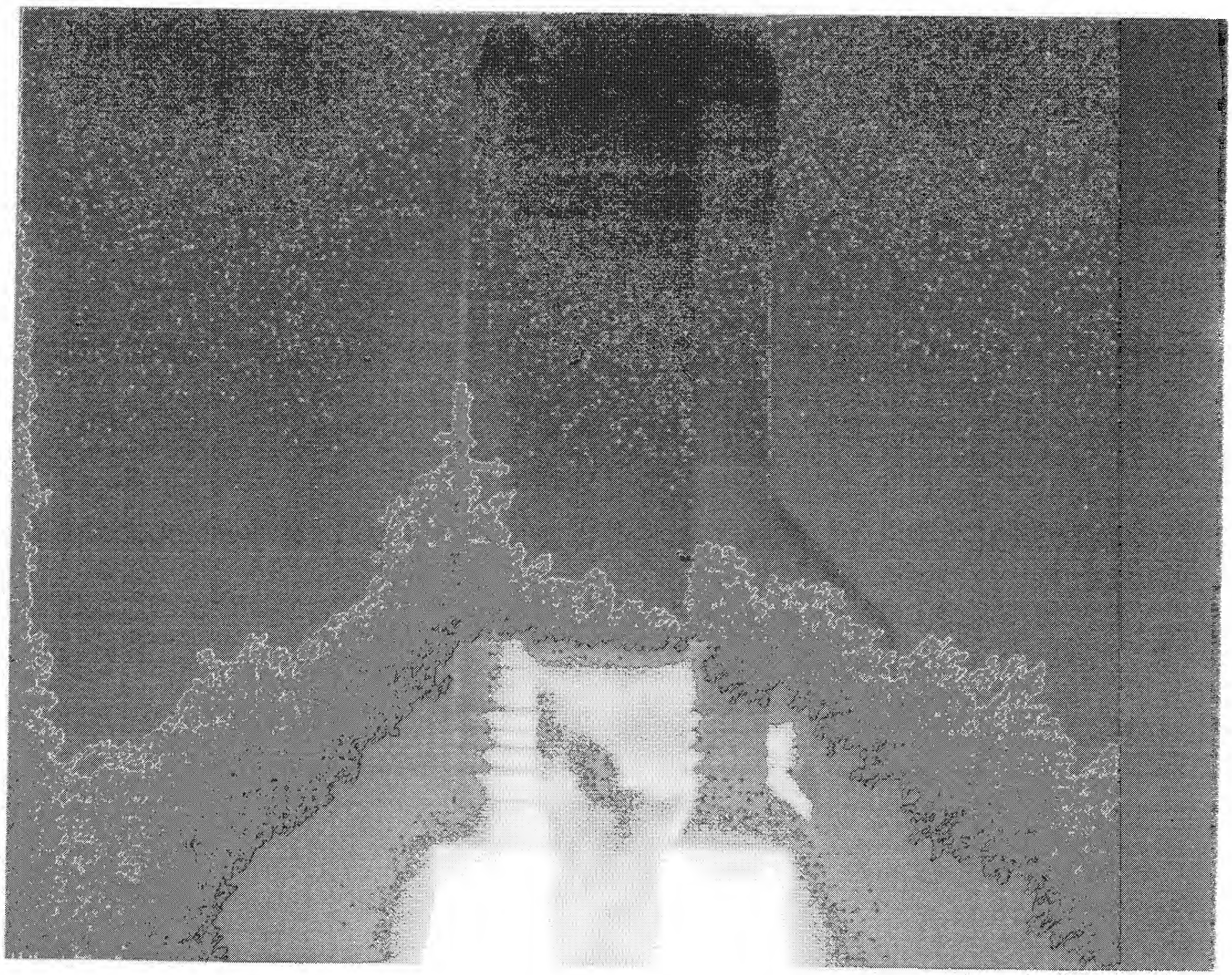
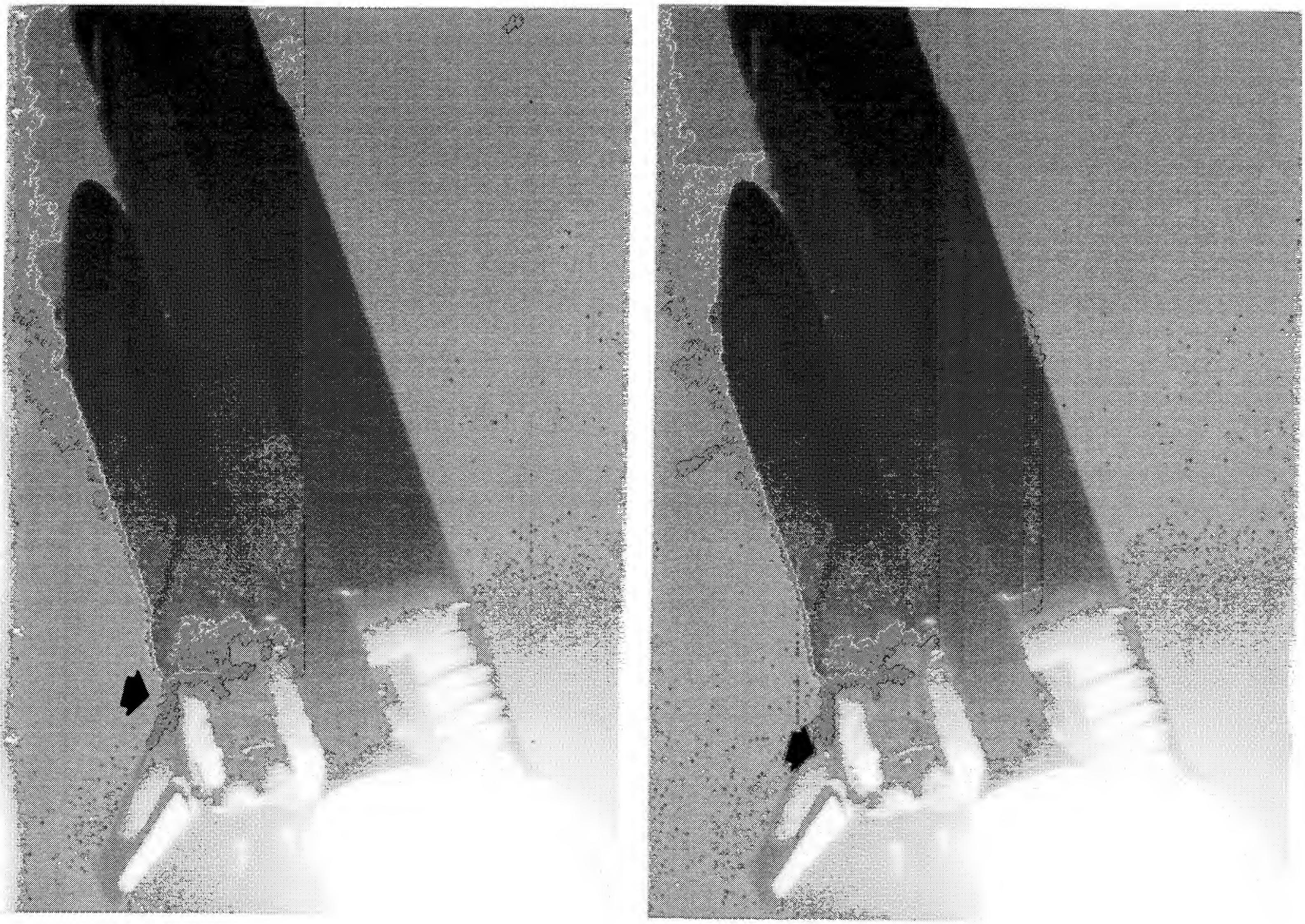


Backlit view of condensate on ET aft dome and water from SRB stiffener rings vaporizing - a normal occurrence



E-207 recorded a piece of white tile screed from the RH outboard elevon falling from the vehicle during the roll maneuver

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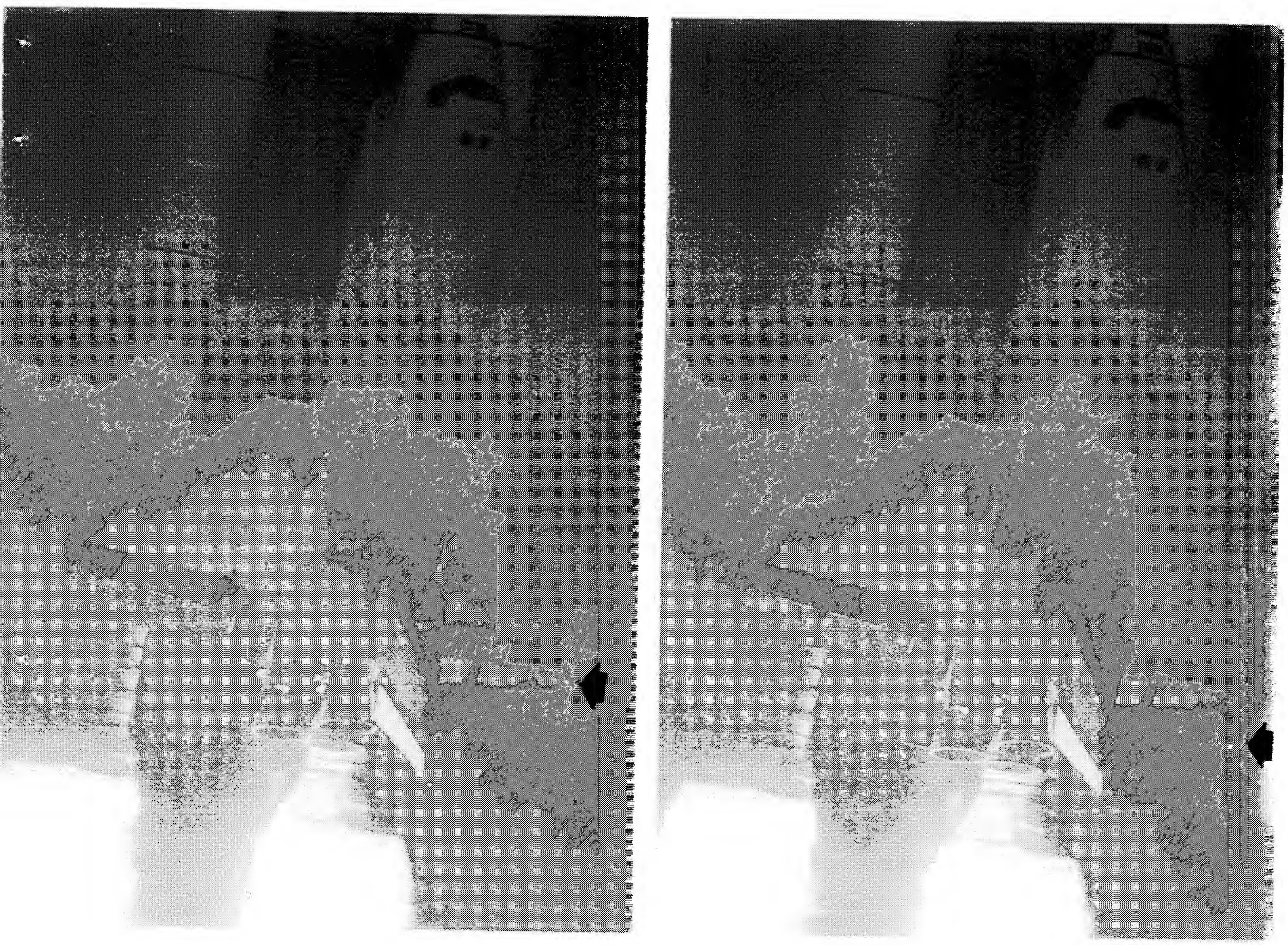

A camera south of the vehicle also recorded the piece of white tile screed falling from the RH outboard elevon

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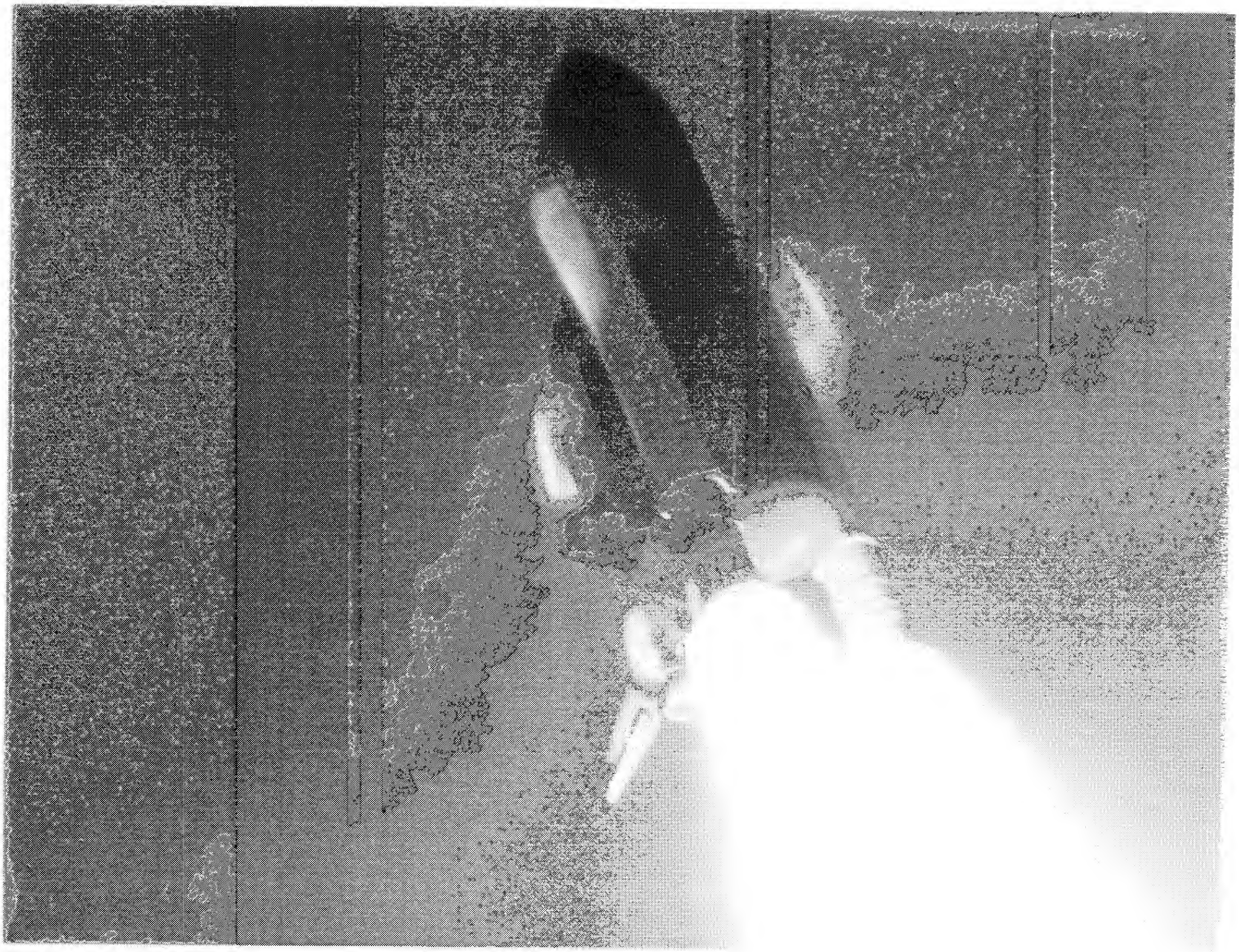
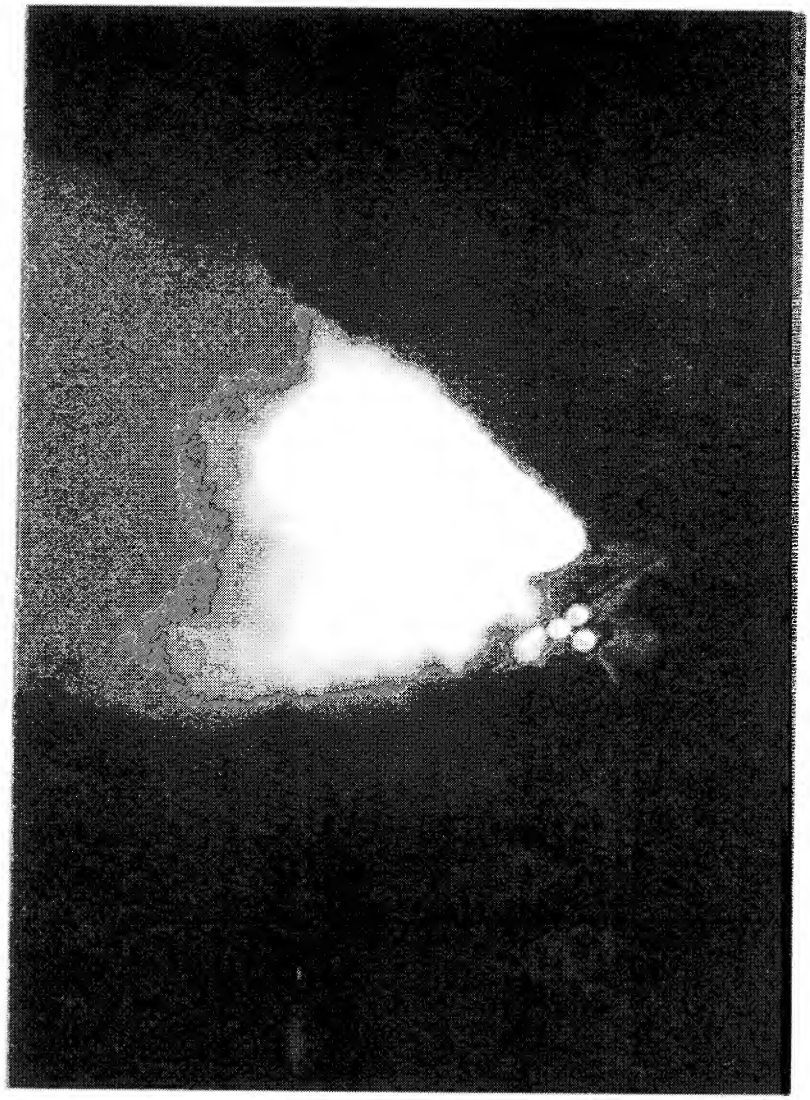
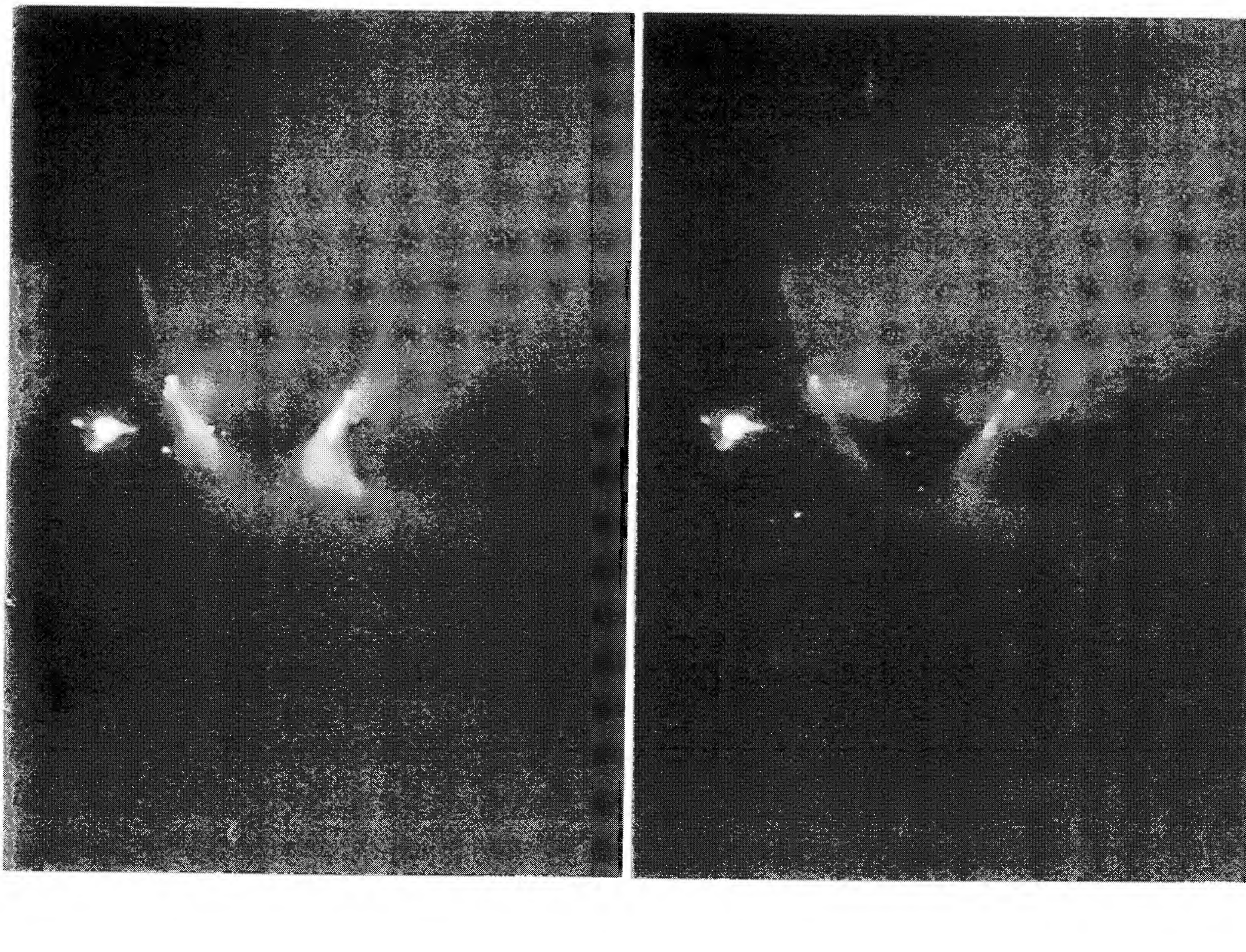


Appearance of local supersonic flow condensate typically occurs in the Max-Q region



A flash occurred in the SSME plume at 43 seconds MET

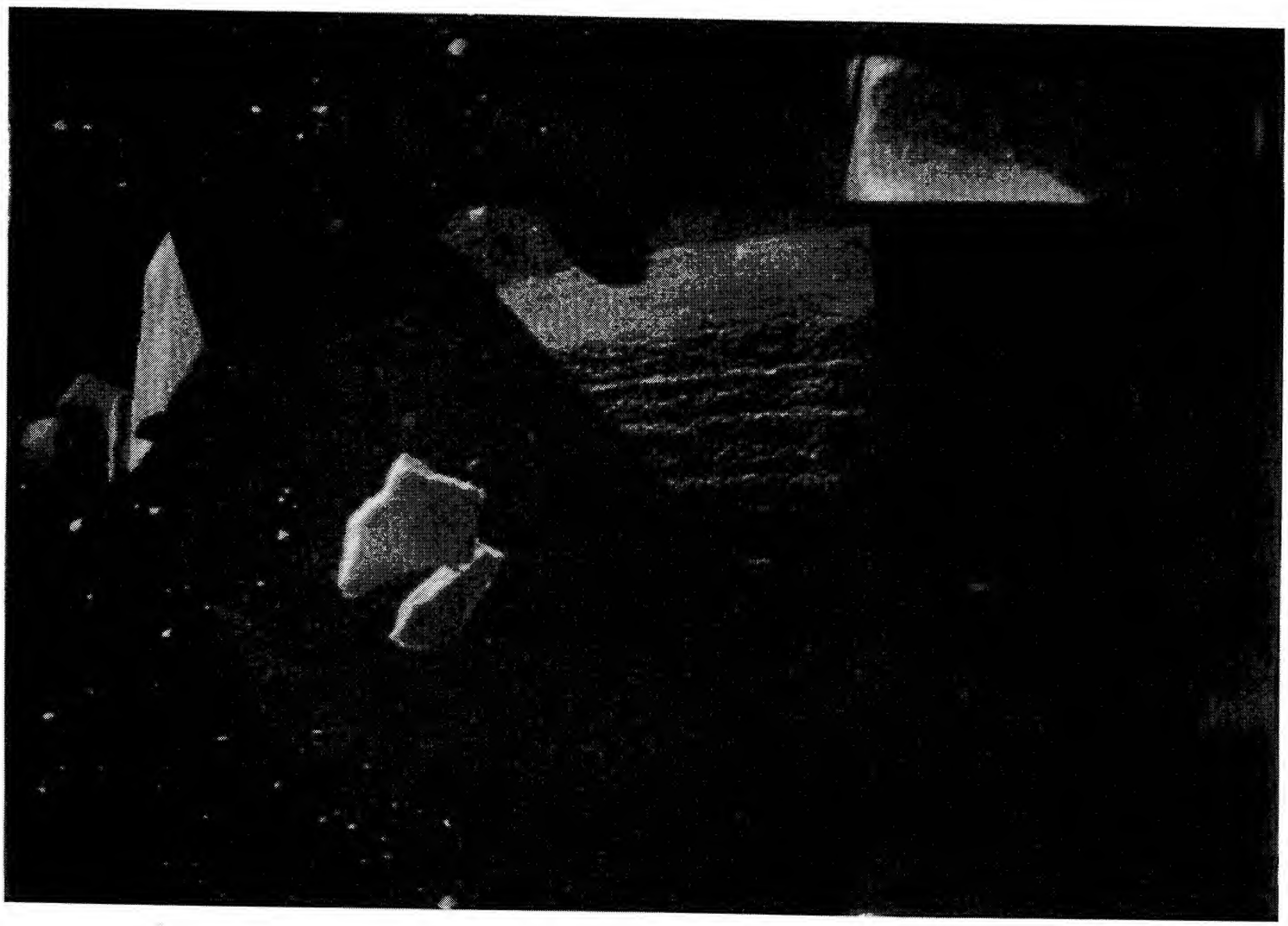


Hundreds of pieces of SRB propellant slag, or clinkers, fall from the SRB plumes before and after separation, a normal event

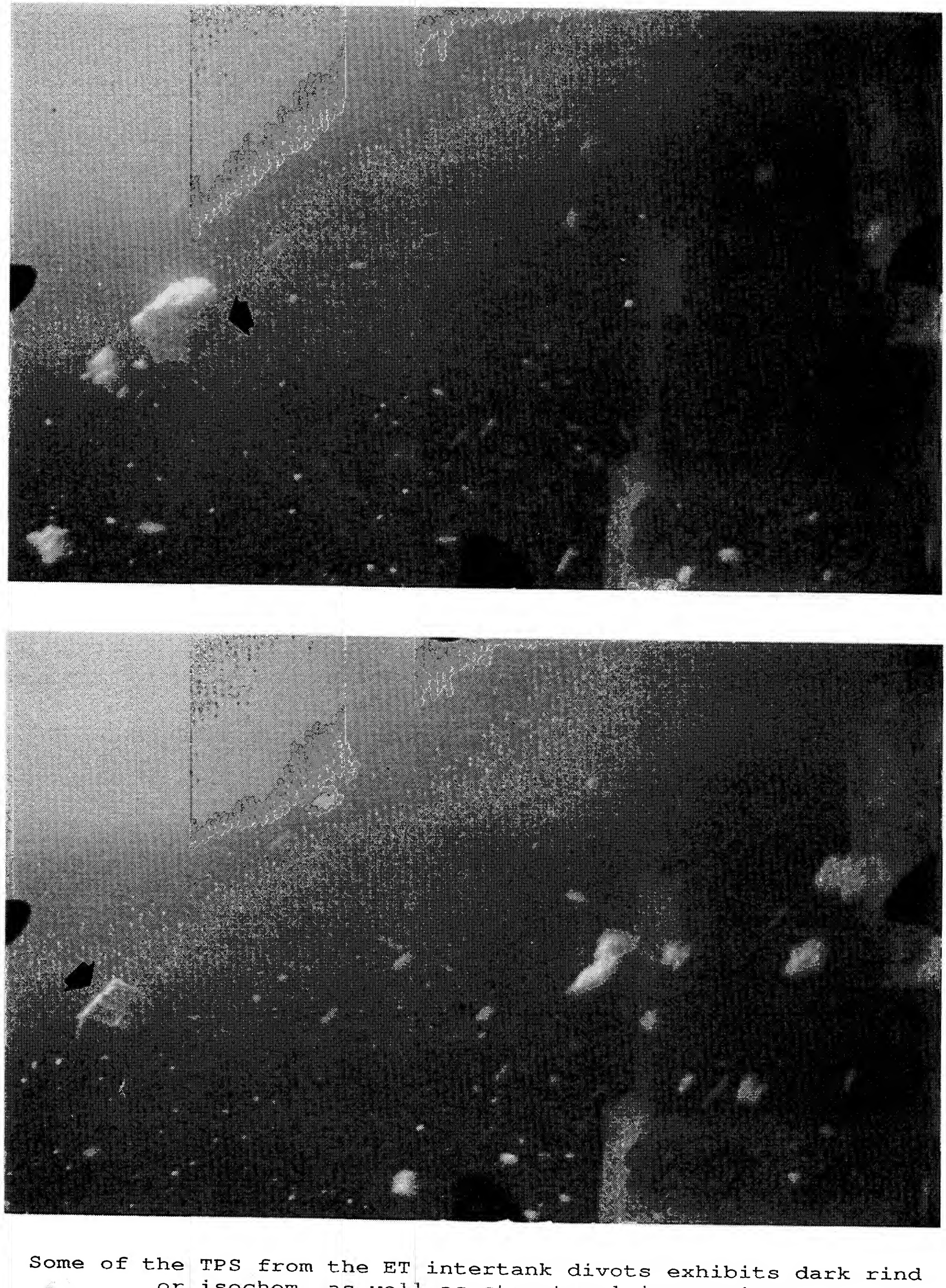
Pieces of ET TPS fall past the LH2 umbilical camera. Note loss of foam from the LH2 umbilical cable tray

Pieces of TPS from ET intertank divots enter FOV (arrow). Note additional loss of foam from the LH2 umbilical cable tray.

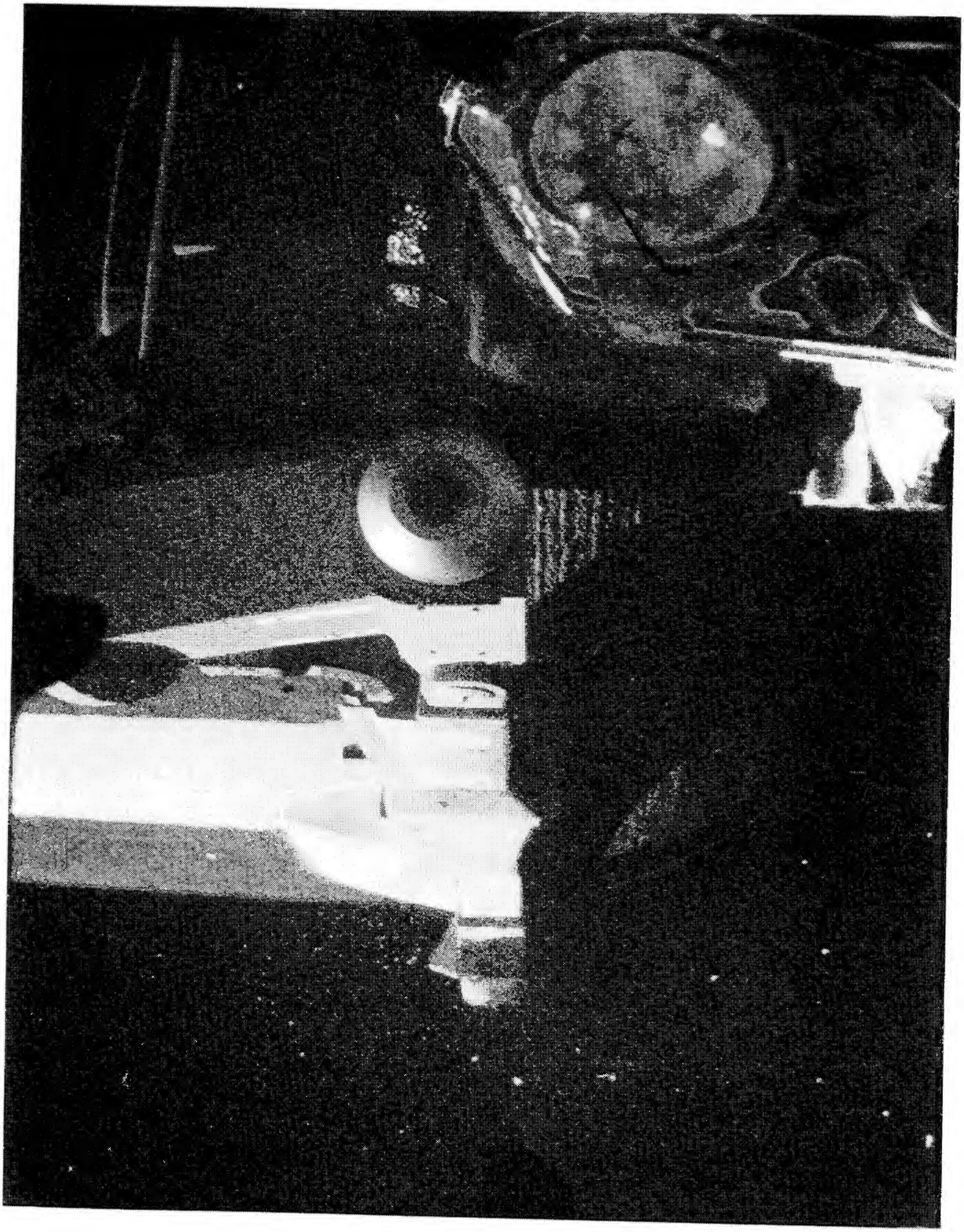
LH2 umbilical cable tray is missing foam from outboard and aft sides. Fire barrier paint has blistered/bubbled.



More ET TPS from the intertank divots falls aft past the umbilical camera. Note isochem line in the TPS (arrow).



Some of the TPS from the ET intertank divots exhibits dark rind or isochem, as well as structural impressions



LH2 17-inch flapper valve is filled with frozen hydrogen. Top left area of umbilical is damaged/covered by frozen hydrogen.

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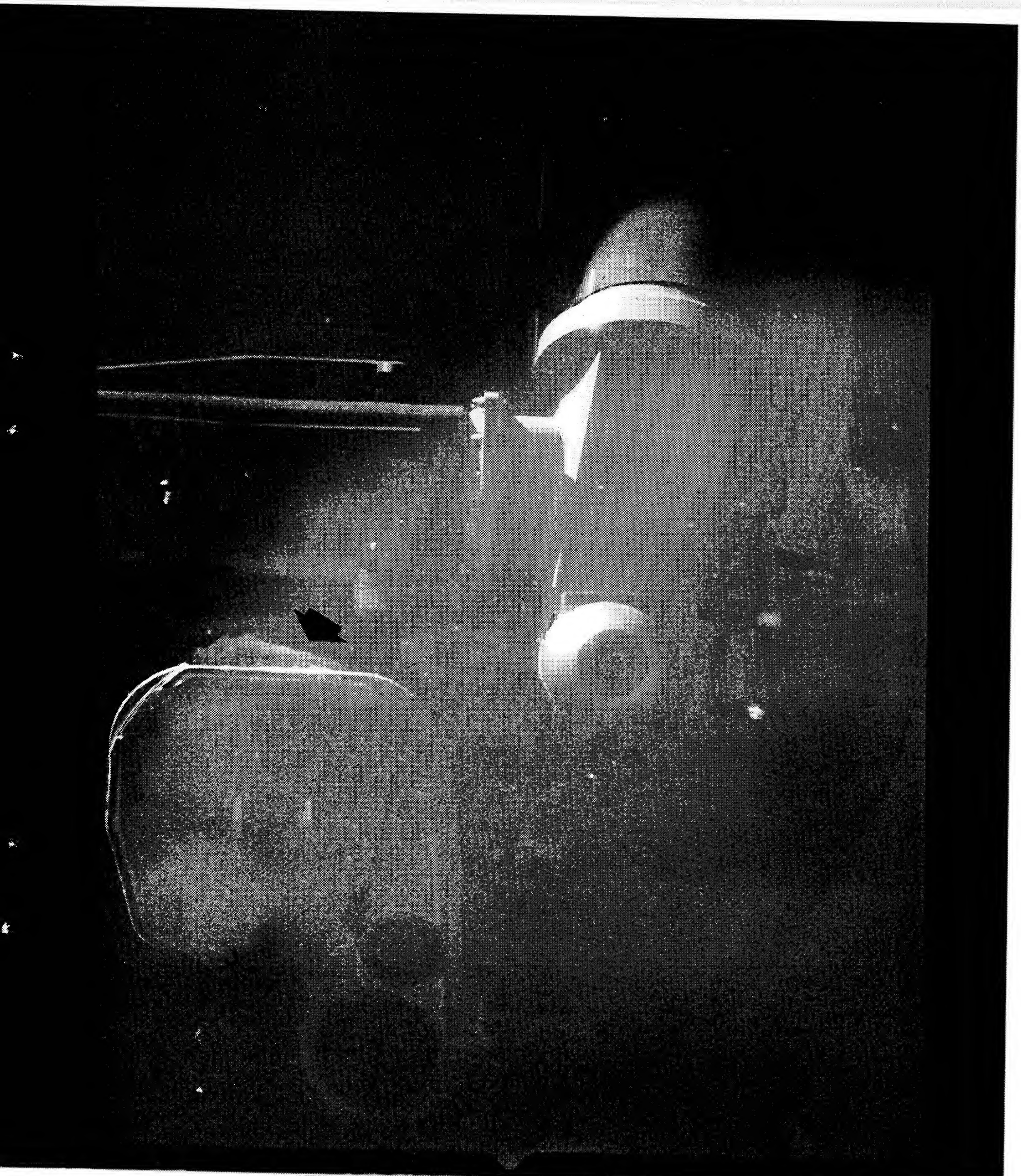

Very little damage is visible on +Y side of ET except for TPS peeled back or ice covering on top side of LO2 umbilical

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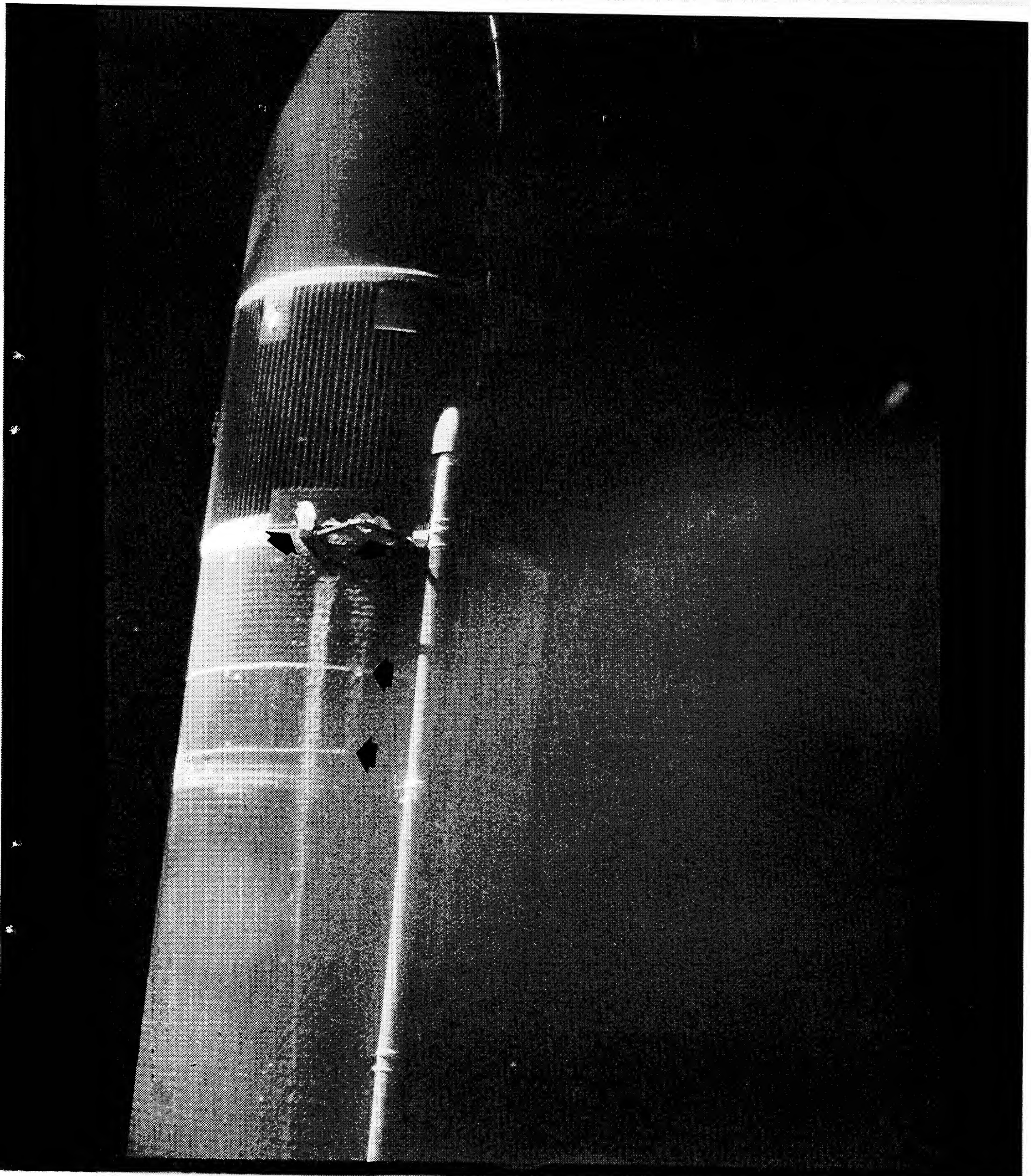


Five divots occurred in the intertank TPS forward of the bipods and 2 divots appear on the LH2 tank acreage at the spray aborts

7.1 LAUNCH FILM AND VIDEO DATA REVIEW

FILM ITEMS

EX1
400 FPS
16mm

Camera is located on MLP deck south of RH SRB exhaust duct and looks north to view RH SRB Heater Umbilical during ignition and liftoff.

Focus : OK
F. O. V.: OK
Exposure: OK

Comments: AFTER SSME IGNITION, SMALL PIECES OF DEBRIS AND K5NA TRIMMINGS APPEAR BEHIND THE DCA. ICE FALLS FROM THE ET/ORB LO2 UMBILICAL AND BOUNCES ON THE MLP DECK. T-0 OCCURS AT FRAME 4147 AND THE DCA OSCILLATES WHEN THE ORDNANCE FIRES. THE HDP SHOE ROCKS SLIGHTLY AT LIFTOFF. THE SRB JOINT HEATER UMBILICAL APPEARS TO SEPARATE PROPERLY. A SMALL, THIN OBJECT, POSSIBLY A PIECE OF INSTAFOAM TRIMMING OR SHIM MATERIAL FROM THE INBOARD NORTHERN CORNER OF THE SHOE, COMES LOOSE AND FALLS INTO THE EXHAUST HOLE. NO DEBRIS FALLS FROM THE AFT SKIRT STUD HOLE. SRB THROAT PLUG MATERIAL IS EJECTED UPWARD OUT OF THE EXHAUST HOLE.

EX2
400 FPS
16mm

Camera is located on the MLP deck west of RH SRB flame duct and looks east to view SRB Heater Umbilical during ignition and liftoff.

Focus : OK
F. O. V.: OK
Exposure: SLIGHTLY UNDEREXPOSED

Comments: ET/ORB UMBILICAL ICE AND FSS WATER DELUGE DROPS FALL TO MLP DECK AFTER SSME IGNITION. THE SRB JOINT HEATER UMBILICAL SEPARATES PROPERLY. SMALL PARTICLES OF INSTAFOAM FALL AWAY FROM THE AFT SKIRT. NO VEHICLE ANOMALIES WERE VISIBLE.

EX3
400 FPS
16mm

Camera is located on the MLP deck east of LH SRB flame duct and looks west to view SRB Heater Umbilical during ignition and liftoff.

Focus : OK
F. O. V.: OK
Exposure: OK

Comments: ET/ORB UMBILICAL ICE AND FSS WATER DELUGE DROPS FALL ON MLP DECK AFTER SSME IGNITION. SEPARATION OF THE SRB JOINT HEATER UMBILICAL IS NOT VISIBLE. NO VEHICLE ANOMALIES.

EX4
400 FPS
16mm

Camera is located on MLP deck south of LH SRB flame duct and looks north to view LH SRB Heater Umbilical during ignition and liftoff.

Focus : OK
F. O. V.: OK
Exposure: OK

Comments: SSME ASPIRATION PULLS SMALL PIECES OF DEBRIS AND K5NA TRIMMINGS FROM BEHIND THE DCA. T-0 OCCURS IN FRAME 4041 AND THE DCA OSCILLATES WHEN THE ORDNANCE IS FIRED. HOLDDOWN POST SHOE ROCKS SLIGHTLY AT T-0. SEPARATION OF THE SRB JOINT HEATER UMBILICAL IS NOT VISIBLE. TWO LARGE AND APPROXIMATELY 11 SMALLER OBJECTS FALL FROM THE SRB AFT SKIRT STUD HOLE AS THE VEHICLE RISES. TYPICAL QUANTITIES OF SRB THROAT PLUG MATERIAL ARE EJECTED FROM THE EXHAUST HOLE.

E-1
400 FPS
16mm

Camera is located on the NE corner of the MLP deck and views the lower ET, SRB's, and Orbiter.

Focus : SOFT
F. O. V.: OK
Exposure: UNDEREXPOSED

Comments: SSME IGNITION OCCURS AT FRAME 2126. SSME START-UP APPEARS NORMAL. DELUGE WATER FROM HYDROGEN VENT LINE HAUNCH PASSES THROUGH RIGHT SIDE OF FOV AS VEHICLE ASCENDS. T-0 OCCURS AT FRAME 4195. WATER FROM THE SRB STIFFENER RINGS VAPORIZES.

E-2
400 FPS
16mm

Camera is located on the SE corner of the MLP deck and views Orbiter SSME and OMS engine nozzles.

Focus : OK
F. O. V.: OK
Exposure: OK

Comments: SSME IGNITION OCCURS IN FRAME 1891. RCS PAPER COVERS TEAR AND FALL AFT. T-0 OCCURS IN FRAME 4168. RESIDUAL LO2 VAPORIZES DURING RETRACTION OF LO2 T-0 UMBILICAL. LH2 TSM DOOR CLOSURE APPEARS NORMAL. RED STREAKS IN THE SSME EXHAUST PLUME OCCUR IN FRAME 4559. STARTING IN FRAME 5129, TWO ICE PARTICLES FALL NEAR THE LH SRB. WATER FROM THE SRB STIFFENER RINGS VAPORIZES.

E-3
400 FPS
16mm

Camera is located on the SW corner of the MLP deck and views Orbiter SSME and OMS engine nozzles.

Comments: FILM ITEM DID NOT RUN.

E-4
400 FPS
16mm

Camera is located on the NW corner of the MLP deck and views lower ET, SRB's, and Orbiter.

Focus : SOFT
F. O. V.: OK
Exposure: UNDEREXPOSED

Comments: SSME IGNITION OCCURS IN FRAME 1863. DELUGE WATER FROM THE GH2 VENT ARM HAUNCH PASSES THROUGH THE FOV. T-0 OCCURS IN FRAME 4323. OVERPRESSURE UPSURGE EJECTS WATER, INSTAFOAM, AND SOUND SUPPRESSION TROUGH MATERIAL FROM SRB EXHAUST HOLES AT SRB IGNITION.

E-5
400 FPS
16mm

Camera is located on the east side of the MLP deck and views the Orbiter RH wing, body flap, and lower ET/SRB.

Focus : OK
F. O. V.: OK
Exposure: OK

Comments: SSME IGNITION OCCURS IN FRAME 1772. ICE PARTICLES FALL FROM THE ET/ORBITER UMBILICAL, PASS BY THE ORBITER BODY FLAP WITHOUT MAKING CONTACT, AND ARE PULLED INTO THE SSME EXHAUST HOLE BY ASPIRATION. ICE PARTICLES FALL FROM THE NOZZLE OF SSME #2 DURING START-UP. T-0 OCCURS IN FRAME 4034. INBOARD AND OUTBOARD ELEVON MOTION IS APPARENT AT T-0. RESIDUAL LO2 VAPORIZES DURING RETRACTION OF THE LO2 T-0 UMBILICAL. IN FRAME 4096, THROAT PLUG MATERIAL IS EJECTED FROM THE RH SRB EXHAUST HOLE, PASSES NEAR THE BODY FLAP, AND PULLED INTO THE SSME EXHAUST HOLE. ANOTHER PARTICLE PASSES NEAR THE BODY FLAP IN FRAME 4321.

E-6
200 FPS
16mm

Camera is located on the east side of the MLP deck and views the RH lower Orbiter wing, body flap, ET lower LOX feedline,and ET/Orbiter umbilical area.

Focus : OK
F. O. V.: OK
Exposure: OK

Comments: ELEVON MOTION IS APPARENT AT SSME START. AN ORANGE GSE TILE SHIM (APPROXIMATELY 4" X 1") FALLS THROUGH FOV IN FRAME 1840. NUMEROUS ICE PARTICLES FALL FROM THE ET/ORBITER UMBILICALS. APPROXIMATELY 12 PARTICLES FALL FROM RH WING UPPER SURFACE. T-0 OCCURS IN FRAME 2325. LH UMBILICAL BAGGIE IS LOOSE AT LIFTOFF.

E-7
400 FPS
16mm

Camera is located on the MLP deck and views the RH SRB northeast holddown post (HDP #4).

Focus : OK
F. O. V.: OK
Exposure: OK

Comments: T-0 OCCURS IN FRAME 4125. A LARGE PIECE OF RTV-LIKE DEBRIS IS BLOWN INTO FOV BY IGNITION AND BOUNCES ON THE MLP DECK. ALL HOLDDOWN POST SHIMS APPEAR INTACT. THE HOLDDOWN POST DOGHOUSE BLAST COVER IS SLOW TO CLOSE. NO DEBRIS FALLS FROM THE AFT SKIRT STUD HOLE.

E-8
400 FPS
16mm

Camera is located on the MLP deck and views the RH SRB southeast holddown post (HDP #2).

Focus : OK
F. O. V.: OK
Exposure: OK

Comments: T-0 OCCURS IN FRAME 4151. TYPICAL AMOUNTS OF IN-STAFOAM, THROAT PLUG, AND SOUND SUPPRESSION WATER TROUGH MATERIAL ARE EJECTED FROM THE SRB EXHAUST HOLE AT IGNITION. NO MOVEMENT OF THE HOLDDOWN POST DEBRIS CONTAINMENT ASSEMBLY IS DETECTABLE. PYRO CABLE SEPARATES NORMALLY. THE HDP SHOE SHIM IS DEBONDED AND PULLED UPWARD BY THE AFT SKIRT FOOT. AS THE VEHICLE RISES, THIS PIECE FALLS BACK DOWN ONTO THE HOLDDOWN POST. NO DEBRIS FALLS FROM THE AFT SKIRT STUD HOLE.

E-9
400 FPS
16mm

Camera is located on the MLP deck and views the RH SRB southwest holddown post (HDP #1).

Focus : OK
F. O. V.: OK
Exposure: OK
Note : MUCH CAMERA SHAKE, POSSIBLY A LOOSE MOUNT

Comments: AN IRREGULAR SHAPED, TRANSLUCENT PIECE OF ICE, ENTERING THE FOV FROM THE TOP OF THE FRAME, FALLS VERTICALLY AND BOUNCES ON THE MLP DECK SLOPED RAMP WITHOUT SHATTERING (FRAME 192 OR GMT 12:34:51.433) BEFORE FALLING INTO THE SRB HDP HAUNCH. THE OBJECT IS NOT SYMMETRIC ABOUT ANY AXIS AND IS NOT A METALLIC WASHER. SWING ARMS ARE ALREADY RETRACTED TO THE FSS AND SSME IGNITION HAS NOT YET OCCURRED. HOWEVER, WATER DELUGE ON THE FSS WAS ACTIVATED AT T-16 SECONDS AND MAY HAVE PROVIDED ENOUGH WATER FLOW WITH THE WESTERLY WINDS TO DISLODGE THE ICE FROM THE VEHICLE. SOME OF THAT WATER SPRAY IS VISIBLE PASSING BY THE RH SRB AFT BSM'S. LATER, AN ICE PARTICLE FROM THE ET/ORBITER UMBILICAL FALLS TO THE MLP DECK AND BOUNCES WITHOUT SHATTERING IN A SIMILAR MANNER. T-0 OCCURS IN FRAME 3627. SEVERAL PIECES OF INSTAFAM TRIMMING ARE EJECTED FROM THE EXHAUST HOLE AT IGNITION. A DEBRIS PARTICLE APPEARS FROM BEHIND THE HOLDDOWN POST AND FALLS INTO THE EXHAUST HOLE. NO DEBRIS FALLS FROM THE AFT SKIRT STUD HOLE.

E-10
400 FPS
16mm

Camera is located on the MLP deck and views the RH SRB northwest holddown post (HDP #3).

Focus : OK
F. O. V.: OK
Exposure: OK

Comments: T-0 OCCURS IN FRAME 4100. ONE OBJECT (NSI SIZE) FALLS FROM THE AFT SKIRT STUD HOLE JUST BEFORE THE AFT SKIRT FOOT CLEARS THE DOGHOUSE BLAST COVER. SRB SOUND SUPPRESSION WATER TROUGH CORD IS BLOWN ACROSS FOV. SEVERAL LIGHT-COLORED OBJECTS, PROBABLY SRB THROAT PLUG MATERIAL, ENTER FOV FROM UPPER LEFT AND FALL INTO THE EXHAUST HOLE.

E-11
400 FPS
16mm

Camera is located on the MLP deck and views the LH SRB northeast holddown post (HDP #7).

Focus : OK
F. O. V.: OK

Exposure: OK

Comments: WATER ON MLP DECK IS DRAWN TOWARD SSME EXHAUST HOLE BY ASPIRATION. T-0 OCCURS IN FRAME 4323. HOLDDOWN POST SHIM MATERIAL APPEARS INTACT. ONE OBJECT FALLS FROM THE SRB AFT SKIRT FOOT. HOLDDOWN POST DOGHOUSE BLAST COVER CLOSES NORMALLY. TWO PIECES OF ICE FALL VERTICALLY THROUGH FOV.

E-12
400 FPS
16mm

Camera is located on the MLP deck and views the LH SRB southeast holddown post (HDP #5).

Focus : OK
F. O. V.: OK
Exposure: OK

Comments: ICE PARTICLES FROM THE ET/ORBITER UMBILICALS AND INSTAFOAM TRIMMINGS ARE PULLED TOWARDS THE SSME EXHAUST HOLE BY ASPIRATION. T-0 OCCURS IN FRAME 3770. NUMEROUS PIECES OF THROAT PLUG MATERIAL AND INSTAFOAM TRIMMINGS ARE EJECTED FROM THE SRB EXHAUST HOLE AT IGNITION. AT LEAST FOUR PIECES OF FRANGIBLE NUT/NSI CARTRIDGE ARE VISIBLE FALLING FROM HDP #5 AFT SKIRT STUD HOLE AS THE VEHICLE RISES. NO SIGNS OF STUD HANG-UP OR OTHER SRB ANOMALIES.

E-13
400 FPS
16mm

Camera is located on the MLP deck and views the LH SRB southwest holddown post (HDP #6).

Comments: FILM ITEM DID NOT RUN.

E-14
400 FPS
16mm

Camera is located on the MLP deck and views the LH SRB northwest holddown post (HDP #8).

Focus : OK
F. O. V.: OK
Exposure: OK

Comments: VIEW IS OBSCURED BY FSS WATER DELUGE. T-0 OCCURS IN FRAME 4046. PYRO CABLE SEPARATES NORMALLY. HOLDDOWN POST DOGHOUSE BLAST COVER IS SLOW TO CLOSE. NO SHIM MATERIAL APPEARS TO BE MISSING. NO MOVEMENT OF THE HOLDDOWN POST DEBRIS CONTAINMENT ASSEMBLY IS DETECTABLE. A LONG NARROW OBJECT PASSES THROUGH THE FOV FROM RIGHT TO LEFT IN FRAME 4295. ONE, PERHAPS TWO, OBJECTS FALL FROM THE AFT SKIRT STUD HOLE (FRAME 4348 THROUGH 4385).

E-15
400 FPS
16mm

Camera is located on the MLP deck and views the RH SRB skirt, sound suppression water troughs, and RH lower Orbiter body flap.

Focus : OK
F. O. V.: OK
Exposure: OK

Comments: SSME IGNITION OCCURS IN FRAME 1257 AND APPEARS NORMAL. ICE PARTICLES FALL FROM THE ET/ORBITER LO2 UMBILICAL. T-0 OCCURS IN FRAME 3562. SRB OVERPRESSURE UPSURGE CAUSES WATER IN THE SRB SOUND SUPPRESSION TROUGHS TO GEYSER 20 FEET UPWARD. TWO PIECES OF INSTAFOAM APPEAR FROM BEHIND HDP #4 AND FALL INTO EXHAUST HOLE. A RIGID PIECE OF FACILITY DEBRIS, POSSIBLY FROM INSIDE ONE OF THE WATER TROUGHS, RISES STRAIGHT UP AND FALLS BACK INTO THE EXHAUST HOLE, BUT IS NOT NEAR THE VEHICLE (FRAME 3616). THROAT PLUG MATERIAL RISES UPWARD THROUGH UPPER LEFT CORNER OF FOV. NO DEBRIS FALLS FROM THE AFT SKIRT STUD HOLES. HDP #3 DOGHOUSE COVER CLOSES PROPERLY.

E-16
400 FPS
16mm

Camera is located on the MLP deck and views the LH SRB skirt, sound suppression water troughs, and LH lower Orbiter body flap.

Focus : OK
F. O. V.: OK
Exposure: OK

Comments: SSME IGNITION OCCURS IN FRAME 2534 AND APPEARS NORMAL. ORBITER BODY FLAP MOTION IS APPARENT DURING SSME START-UP. NUMEROUS ICE PARTICLES FALL FROM THE ET/ORBITER LH2 UMBILICAL AT SSME IGNITION. T-0 OCCURS IN FRAME 4864. SRB OVERPRESSURE UPSURGE CAUSES WATER IN THE SRB SOUND SUPPRESSION TROUGHS TO GEYSER 20 FEET UPWARD. PARTICLES OF INSTAFOAM AND WATER TROUGH MATERIAL ARE EJECTED FROM THE SRB EXHAUST HOLE. THE HOLDDOWN POST DOGHOUSE COVERS CLOSE NORMALLY.

E-17
400 FPS
16mm

Camera is located on the MLP deck and views the -Z side of the LO2 T-0 Umbilical and TSM.

Focus : OK
F. O. V.: OK
Exposure: OK

Comments: SSME IGNITION OCCURS IN FRAME 5415. ORBITER BODY FLAP MOTION IS APPARENT DURING SSME START-UP. RCS PAPER COVERS TEAR AND FALL. ICE PARTICLES FROM THE ET/ORBITER UMBILICAL AND THE

SSME #3 DRAIN LINE FALL AT IGNITION. CONDENSATE ON THE ORBITER BASE HEAT SHIELD VAPORIZES. T-0 OCCURS IN FRAME 9885. ALTHOUGH A LARGE QUANTITY OF GOX IS RELEASED, LO2 T-0 UMBILICAL RETRACTION APPEARS NORMAL. A FEW TILES ARE CHIPPED ON THE AFT FACE OF THE RH OMS POD STINGER.

E-18
400 FPS
16mm

Camera is located on the MLP deck and views the -Z side of the LH2 T-0 umbilical and TSM.

Focus : SLIGHTLY SOFT
F. O. V.: OK
Exposure: OK

Comments: SSME IGNITION OCCURS IN FRAME 2357. RCS PAPER COVERS TEAR AND FALL. ICE PARTICLES FROM THE ET/ORBITER LH2 UMBILICAL FALL AT IGNITION. CONDENSATE VAPORIZES ON THE ORBITER BASE HEAT SHIELD. ORBITER BODY FLAP MOTION IS APPARENT DURING SSME START-UP. LH2 T-0 UMBILICAL RETRACTION (FRAME 2357) APPEARS NORMAL. RESIDUAL LH2 VAPORIZES DURING T-0 RETRACTION AND IS DRAWN AFT BY ASPIRATION. ONE TILE IS CHIPPED ON THE ORBITER BASE HEAT SHIELD.

E-19
400 FPS
16mm

Camera is located on the SE side of the MLP deck and views the SSME/OMS nozzles and Orbiter aft heat shield area.

Focus : OK
F. O. V.: OK
Exposure: OK

Comments: HYDROGEN LEAD PRECEDES SSME #1 IGNITION. SSME #3 START OCCURS IN FRAME 2012. ATMOSPHERIC WATER VAPOR VAPORIZES AROUND ALL SSME NOZZLES. RCS PAPER COVERS TEAR AND FALL. NUMEROUS ICE PARTICLES FALL FROM THE SSME NOZZLES AND THE LO2 T-0 UMBILICAL. LO2 T-0 UMBILICAL RETRACTION APPEARS NORMAL. A LARGE QUANTITY OF RESIDUAL LO2 VAPORIZES DURING T-0 UMBILICAL RETRACTION AND IS DRAWN AFT BY ASPIRATION.

E-20
400 FPS
16mm

Camera is located on the SW side of the MLP deck and views the SSME/OMS nozzles and Orbiter aft heat shield area.

Focus : OK
F. O. V.: OK
Exposure: OK

Comments: HYDROGEN LEAD PRECEDES SSME #1 IGNITION. SSME IGNITION OCCURS AT FRAME 1964. RCS PAPER COVERS TEAR AND ICE FALLS FROM THE LH2 T-0 UMBILICAL DURING SSME IGNITION. T-0 OCCURS AT FRAME 4234. LH2 T-0 UMBILICAL DISCONNECT AND RETRACTION IS NORMAL. A NORMAL AMOUNT OF RESIDUAL VAPORS FROM THE UMBILICAL ARE DRAWN INTO THE PLUME BY ASPIRATION. FOUR TILE DINGS ON THE BASE HEAT SHIELD BETWEEN SSME #1 AND #2 AND ONE ON THE LH RCS STINGER WERE CAUSED BY IGNITION ACOUSTICS. A PIECE OF TORN RCS PAPER COVER FLUTTERS JUST ABOVE SSME #1 NOZZLE EXIT PLANE. ATMOSPHERIC WATER VAPOR VAPORIZES AROUND ALL SSME NOZZLES. AN INSTRUMENTED TILE (DARK SPOT) IS VISIBLE ON THE RH OUTBOARD ELEVON UPPER LH CORNER.

E-21
200 FPS
16mm

Camera is located inside the LO2 TSM and views the disconnection of the T-0 umbilical.

Focus : OK
F. O. V.: OK
Exposure: OK

Comments: ICE PARTICLES FALL FROM THE T-0 UMBILICAL FLEXLINES DURING SSME START-UP. T-0 OCCURS IN FRAME 4414. RESIDUAL LO2 VAPORIZES AS THE T-0 UMBILICAL SEPARATES AND IS DRAWN AFT BY SSME ASPIRATION. SEPARATION AND RETRACTION OF THE UMBILICAL APPEARS NORMAL. TSM DOOR CLOSES NORMALLY AND DOES NOT REBOUND. AN INSECT DROPS THROUGH FOV SHORTLY AFTER DOOR CLOSURE. AN OBJECT, WHICH APPEARS TO BE A PIP-PIN WITH A COTTER PIN THROUGH ONE END, FALLS THROUGH FOV JUST PRIOR TO END OF ITEM AFTER VEHICLE HAS CLEARED THE TOWER.

E-22
200 FPS
16mm

Camera is located inside the LH2 TSM and views the disconnection of the T-0 umbilical.

Focus : OK
F. O. V.: OK
Exposure: OK

Comments: CABLE IS HANGING ACROSS FOV INSIDE TSM. PURGE BARRIER FALLS AT SSME IGNITION. T-0 OCCURS IN FRAME 2194. UMBILICAL SEPARATION AND RETRACTION APPEARS NORMAL. TSM DOOR CLOSES NOR-

MALLY AND DOES NOT REBOUND. CABLE HANGING IN FRONT OF THE CAMERA WHIPS AROUND THROUGH LEFT SIDE OF FOV AFTER DOOR CLOSURE. TSM FILLS WITH SMOKE SHORTLY AFTER T-0.

E-23
400 FPS
16mm

Camera is located on the MLP deck and views the RH OMS engine nozzle.

Focus : OK
F. O. V.: OK
Exposure: OK

Comments: SSME IGNITION OCCURS IN FRAME 2153. FREE BURNING HYDROGEN BURNS OUTSIDE AND ABOVE NOZZLES. OMS NOZZLE VIBRATES DURING SSME START-UP. RCS PAPER COVERS TEAR AND FALL. SSME #1 HATBAND INSULATION EXHIBITS MORE VIBRATION/MOVEMENT THAN USUAL. ICE PARTICLES FALL FROM BOTH THE LO2 T-0 UMBILICAL AND THE SSME LO2 SEAL DRAIN LINES. ATMOSPHERIC WATER VAPOR VAPORIZES AROUND THE SSME NOZZLES. T-0 OCCURS IN FRAME 4240. RESIDUAL LO2 VAPORIZES UPON T-0 DISCONNECT AND IS DRAWN AFT BY ASPIRATION. LO2 TSM DOOR CLOSES NORMALLY.

E-24
400 FPS
16mm

Camera is located on the MLP deck and views the LH OMS engine nozzle.

Focus : OK
F. O. V.: OK
Exposure: OK

Comments: SSME IGNITION OCCURS IN FRAME 2267. OMS NOZZLE VIBRATES DURING SSME START-UP. ICE PARTICLES FALL FROM THE LO2 T-0 UMBILICAL AND SSME #1 NOZZLE. RCS PAPER COVERS TEAR AND FALL. ATMOSPHERIC WATER VAPOR VAPORIZES AROUND THE SSME NOZZLES. T-0 OCCURS IN FRAME 4335. RESIDUAL LH2 VAPORIZES UPON T-0 DISCONNECT AND IS DRAWN AFT BY ASPIRATION. ICE PARTICLES FALL FROM THE ET/ORBITER LH2 UMBILICAL AS THE VEHICLE RISES.

E-25
400 FPS
16mm

Camera is located on the east side of the MLP and views between Orbiter and ET/SRB during liftoff.

Focus : OK
F. O. V.: SLIGHTLY HIGH
Exposure: UNDEREXPOSED

Comments: SSME IGNITION OCCURS IN 1332. IN FRAME 1803, A PARTICLE RISES IN LEFT PART OF FOV NEAR THE ORBITER WING AND THEN FALLS TO THE MLP DECK IN THE RIGHT OF FOV. ELEVON MOTION IS APPARENT DURING SSME START-UP. A PARTICLE FALLS BETWEEN THE ELEVON GAP AND TOP OF TSM IN FRAME 2511. NUMEROUS ICE PARTICLES FALL FROM THE ET/ORBITER UMBILICALS. IN FRAME 3568 A PARTICLE PASSES ACROSS THE TOP OF THE FOV FROM NORTH TO SOUTH. PARTICLES PASS OVER THE RH WING IN FRAME 3814. RCS PAPER COVERS FALL AFT OF THE VEHICLE IN FRAME 4269.

E-26
400 FPS
16mm

Camera is located on the west side of the MLP and views between Orbiter and ET/SRB during liftoff.

Focus : SOFT
F. O. V.: TOO HIGH
Exposure: UNDEREXPOSED

Comments: SSME IGNITION OCCURS IN FRAME 1350. ICE PARTICLES FALL FROM THE LH2 ET/ORBITER UMBILICAL. DELUGE WATER FROM THE GH2 VENT LINE HAUNCH PASSES THROUGH THE FOV. T-0 OCCURS IN FRAME 3429. RESIDUAL HYDROGEN VAPOR TRAILS FROM THE ORBITER LH2 FLIGHT QD AS THE VEHICLE ASCENDS.

E-27
400 FPS
16mm

Camera is located on the MLP deck and views RH SRB northwest holddown post (HDP #3) blast cover.

Focus : OK
F. O. V.: OK
Exposure: OK
Note : EXCESSIVE CAMERA SHAKE

Comments: T-0 OCCURS IN FRAME 4055. A LARGE PIECE OF THROAT PLUG MATERIAL FALLS INTO THE SRB EXHAUST HOLE IN FRAME 4389. HOLDDOWN POST #3 DOGHOUSE BLAST COVER IS SLOW TO CLOSE.

E-28
400 FPS
16mm

Camera is located on the MLP deck and views LH SRB northeast holddown post (HDP #7) blast cover.

Focus : OK
F. O. V.: OK
Exposure: OK

Comments: VISIBILITY DEGRADED DUE TO SUN ANGLE AND FSS WATER DELUGE. ONE PARTICLE FALLS FROM HOLDDOWN POST #8 AFT SKIRT STUD HOLE IN FRAME 4456. SHIM MATERIAL APPEARS TO REMAIN BONDED TO AFT SKIRT FOOT. HOLDDOWN POST DOGHOUSE BLAST COVER CLOSES PROPERLY.

E-30
400 FPS
16mm

Camera is located on the FSS 195 foot level and views LH SRB and sound suppression water troughs.

Focus : OK
F. O. V.: OK
Exposure: UNDEREXPOSED

Comments: VISIBILITY DEGRADED DUE TO FSS WATER DELUGE. SSME IGNITION OCCURS IN FRAME 1978. ICE PARTICLES FALL FROM THE ET/ORBITER UMBILICALS. T-0 OCCURS IN FRAME 4110.

E-31
100 FPS
16mm

Camera is located on the FSS 95 foot level and views the LH Orbiter wing, body flap, and ET/Orbiter LH2 umbilical area.

Focus : OK
F. O. V.: OK
Exposure: UNDEREXPOSED

Comments: SSME IGNITION OCCURS IN FRAME 823. ATMOSPHERIC WATER VAPOR VAPORIZES AROUND SSME #2 AND #3 NOZZLES. ICE PARTICLES AND VAPORS FALL FROM THE ET/ORBITER UMBILICALS AT SSME IGNITION AND PASS BY THE BODY FLAP WITHOUT CAUSING TILE DAMAGE. IN FRAME 978, A SLOW MOVING 2" X 4" PARTICLE FALLS FROM THE ET/ORBITER LO2 UMBILICAL CABLE TRAY. ELEVON MOTION IS APPARENT DURING SSME START-UP. T-0 OCCURS IN FRAME 1625. CONDENSATE VAPORIZES ON THE ET AFT DOME.

E-33
200 FPS
16mm

Camera is located on the FSS 235 foot level and views the ET GH2 vent line and GUCP.

Focus : OK
F. O. V.: OK
Exposure: OK

Comments: VIEW OBSCURED BY FSS DELUGE WATER. ICE/FROST FORMED ON THE GH2 VENT ARM, AROUND THE PERIMETER OF THE FLIGHT CARRIER ASSEMBLY, AND ON THE GROUND UMBILICAL CARRIER PLATE. A SMALL AREA OF ICE/FROST IS ALSO PRESENT ON AN INTERTANK STRINGER NEAR THE SPLICE. T-0 OCCURS IN FRAME 5088. VEHICLE "WALKS" APPROXIMATELY 14 FEET TO THE NORTH.

E-34
300 FPS
16mm

Camera is located on FSS at 255 foot level and views upper Orbiter tile surfaces.

Focus : SOFT
F. O. V.: OK
Exposure: SLIGHTLY UNDEREXPOSED

Comments: T-0 OCCURS IN FRAME 2123. FACILITY DELUGE WATER CROSSES FOV. GUCP SEPARATION APPEARS NORMAL. HYDROGEN FIRE DETECTION BUTCHER PAPER ON THE ET STRUT IS STILL INTACT AS THE VEHICLE ASCENDS.

E-35
300 FPS
16mm

Camera is located on the FSS 255 foot level and views the mid-Orbiter/ET/SRB area.

Focus : SOFT
F. O. V.: SLIGHTLY TOO FAR RIGHT
Exposure: SLIGHTLY UNDEREXPOSED

Comments: FACILITY DELUGE WATER IS BLOWN EAST BY WESTERLY WINDS. SSME IGNITION OCCURS IN FRAME 632. T-0 OCCURS IN FRAME 2203. VEHICLE WALKS NORTH APPROXIMATELY 20 FEET. NO DEBRIS OR VEHICLE ANOMALIES ARE OBSERVED THROUGH LOV.

E-36
300 FPS
16mm

Camera is located on the FSS 255 foot level and views lower Orbiter, ET, SRB's, and water trough.

Focus : OK
F. O. V.: OK
Exposure: UNDEREXPOSED

Comments: SSME IGNITION OCCURS IN FRAME 827. T-0 OCCURS IN FRAME 2525. SRB SOUND SUPPRESSION WATER TROUGHS REACT TO IGNITION OVER-PRESSURE UPSURGE AND WATER IN THE SOUND SUPPRESSION TROUGHS GEYSERS UPWARD. LH2 T-0 UMBILICAL DISCONNECT AND RETRACTION APPEARS NORMAL. GH2 VENT ARM RETRACTION ALSO APPEARS NORMAL. AFTER VEHICLE LEAVES FOV, A PARTICLE WEST OF THE LH2 TSM FALLS FROM THE NORTH (FRAME 3314). IN FRAME 3425, ANOTHER PARTICLE FALLS FROM THE NORTH TO THE WEST OF THE LH2 TSM.

E-39
300 FPS
16mm

Camera is located on the FSS 185 foot level and views GH2 vent line latchback.

Focus : OK
F. O. V.: OBSCURED BY FSS DELUGE WATER
Exposure: UNDEREXPOSED UNTIL MPS IGNITION

Comments: VIEW COMPLETELY DARK UNTIL GH2 VENT LINE WAS RETRACTED AND LATCHED. WHEN IMAGE APPEARS, IT IS QUICKLY OBSCURED BY DELUGE WATER AND SRB PLUME. NO USEFUL DATA.

E-40
300 FPS
16mm

Camera is located on the FSS 275 foot level and views the ET ogive, SRB nosecone, and Orbiter tiled surfaces.

Focus : OK
F. O. V.: OK
Exposure: UNDEREXPOSED

Comments: LIGHT FROST COVERS THE LOUVER. DUE TO THE COLDER WEATHER, GOX VAPORS ARE VISIBLE BLOWING SOUTHEAST PAST THE NOSECONE FAIRING. VEHICLE TWANG LOOKS NORMAL. T-0 OCCURS IN FRAME 2450. GOX VAPORS INCREASE AT LIFTOFF AND CONTINUE TO BE VISIBLE AS VEHICLE ASCENDS. NO TPS ANOMALIES. CONDENSATE ON THE ET AFT DOME AND WATER FROM THE SRB STIFFENER RINGS VAPORIZES. WATER VAPORS/CONDENSATE EMANATE FROM THE SPLIT IN THE RUDDER SPEED BRAKE. A WHITE OBJECT FIRST APPEARS IN FRAME 3725 NEAR THE LEADING EDGE OF THE LH OMS POD AND MOVES PAST THE VERTICAL STABILIZER, BUT IS NOT NEAR THE VEHICLE. RESIDUAL VAPORS CONTINUE TO

EXIT THE LH2 FLIGHT QD AS THE VEHICLE ASCENDS. MUCH FACILITY DEBRIS PASSES THROUGH THE FOV WELL AFTER THE VEHICLE CLEARS THE TOWER (SOME PIECES OF GOX VENT HOOD WINDOWS).

E-41
300 FPS
16mm

Camera is located on the FSS 255 foot level and views the GH2 vent line during rotation. Also shows clearance between structure and SRB aft skirt.

Focus : OK
F. O. V.: OK
Exposure: UNDEREXPOSED

Comments: ATMOSPHERIC WATER VAPOR CONDENSES AROUND THE GUCP. T-0 OCCURS IN FRAME 2368. FACILITY DEBRIS PARTICLES FALL THROUGH FOV FROM ABOVE PRIOR TO VEHICLE CLEARING TOWER. THE GH2 VENT LINE STATIC LANYARD EXHIBITS SOME SLACK. MORE FACILITY DEBRIS CROSSES FOV AFTER VEHICLE CLEARS TOWER.

E-42
300 FPS
16mm

Camera is located on the FSS 185 foot level and views the GH2 vent line drop, deceleration, and latchback.

Focus :
F. O. V.:
Exposure:

Comments: FILM ITEM RAN FOR A SHORT TIME, THEN JAMMED.

E-44
300 FPS
16mm

Camera is located on the FSS 155 foot level and views the LH OMS Pod leading edge tiles during ignition and liftoff.

Focus : OK
F. O. V.: OK
Exposure: OK

Comments: T-0 OCCURS IN FRAME 2081. RESIDUAL HYDROGEN VAPOR TRAILS FROM ORBITER LH2 FLIGHT QD AND WATER CONDENSATE STREAMS FROM THE RUDDER SPEED BRAKE SPLIT AS THE VEHICLE RISES. RCS PAPER COVERS TEAR AND FALL. NO ORBITER TPS ANOMALIES.

E-48
300 FPS
16mm

Camera is located on the FSS 215 foot level (ET Intertank access arm structure) and views the GH2 vent line during GUCP disconnection, rotation, and latchback

Focus : OK
F. O. V.: OK
Exposure: UNDEREXPOSED

Comments: T-0 OCCURS IN FRAME 2158. DETAILS ON THE FLIGHT CARRIER PLATE ARE NOT VISIBLE AT T-0 DUE TO EXPOSURE PROBLEMS. SEVERAL ICE PARTICLES FALL FROM THE GUCP AT T-0. CONDENSATE ON THE ET AFT DOME AND WATER FROM THE SRB STIFFENER RINGS VAPORIZES AS THE VEHICLE RISES.

E-50
60 FPS
16mm

Camera is located at camera site 1 at NE pad perimeter and views entire GH2 vent line and GUCP during rotation and latchback.

Focus : OK
F. O. V.: OK
Exposure: OK

Comments: ATMOSPHERIC WATER VAPOR CONDENSES AROUND THE GUCP. T-0 OCCURS IN FRAME 2943. GH2 VENT LINE ROTATION APPEARS NORMAL. VENT LINE STATIC LANYARD EXHIBITS EXCESSIVE SLACK DURING RETRACTION. VENT LINE IS LATCHED IN FRAME 3505. DUE TO THE SLACK, THE STATIC LANYARD CABLE LOOPS AS THE ARM LATCHES.

E-52
96 FPS
35mm

Camera is located at camera site 2 on the east pad perimeter. Remote tracking of lower one-third of launch vehicle from ignition to 1200 feet.

Focus : OK
F. O. V.: OK
Exposure: OK

Comments: SSME IGNITION APPEARS NORMAL. ICE/FROST PARTICLES AND VAPORS FROM THE ET/ORBITER UMBILICALS FALL PAST THE BODY FLAP AT SSME IGNITION AND ARE PULLED INTO THE SSME EXHAUST HOLE BY ASPIRATION. PARTICLES OF THROAT PLUG MATERIAL ARE THROWN NORTH AT IGNITION. ICE/FROST PARTICLES FALL FROM THE FSS AND MLP CRYO LINES AT T-0. CONDENSATE ON THE ET AFT DOME AND WATER IN THE SRB STIFFENER RINGS VAPORIZES. ICE PARTICLES CONTINUE TO FALL FROM THE ET/ORBITER UMBILICALS AS THE VEHICLE RISES. TWO PIECES OF ICE FALL FROM EB-8 FITTING IN FRAMES 70-11 AND 71-14. NUMEROUS PIECES OF RCS PAPER COVERS FALL FROM THE VEHICLE DURING EARLY ASCENT. A FLASH IN THE SSME PLUME, CAUSED BY THE COMBUSTION OF AN RCS PAPER

COVER, APPEARS IN FRAME 91-12. A PIECE OF WHITE TILE FALLS FROM THE RH OUTBOARD ELEVON UPPER SURFACE JUST BEFORE THE COMPLETION OF THE ROLL MANEUVER. NO ET AFT DOME CHARRING OR BODY FLAP MOTION IS APPARENT DURING EARLY ASCENT.

E-53
96 FPS
35mm

Camera is located at camera site 2 on the east pad perimeter. Remote tracking of middle one-third of launch vehicle from ignition to 1200 feet.

Focus : OK
F. O. V.: OK
Exposure: OK

Comments: SEE COMMENTS FOR ITEM E-52.

E-54
96 FPS
35mm

Camera is located at camera site 2 on the east pad perimeter. Remote tracking of upper one-third of launch vehicle from ignition to 1200 feet.

Focus : OK
F. O. V.: OK
Exposure: OK

Comments: VEHICLE "TWANG" IS APPARENT DURING SSME START-UP. CONDENSATE ON THE ET AFT DOME VAPORIZES. NO ANOMALIES DURING EARLY ASCENT. AN RCS PAPER COVER FROM THE RH OMS POD STINGER FALLS THROUGH SSME PLUME IN FRAME 103-00. NO APPARENT BODY FLAP MOTION. FRCS PAPER COVERS REMAIN ATTACHED THROUGH LOV. TRACKING OF VEHICLE IS GOOD AFTER LIFTOFF, BUT IS SOON LOST. ONCE REGAINED, VIEW IS OBSCURED BY PLUME AND NO DETAIL IS VISIBLE.

E-57
96 FPS
35mm

Camera is located at camera site 6 on the NW pad perimeter. Remote tracking of lower one-third of launch vehicle from ignition to 1200 feet.

Focus : OK
F. O. V.: TRACKING IS ERRATIC
Exposure: OK

Comments: CONDENSATE FALLS FROM ET AFT DOME AND FROST/VAPORS FALL FROM THE FSS CRYO VENT LINES AT SSME IGNITION. CONDENSATE ON THE ET AFT DOME AND WATER ON THE SRB STIFFENER RINGS VAPORIZES AS THE VEHICLE RISES. ICE FALLS FROM THE EB-8 FITTING AS VEHICLE CLEARS TOWER. NUMEROUS PIECES OF RCS PAPER COVER FALL FROM THE VEHICLE DURING EARLY ASCENT. A FRAGMENT OF WHITE TILE FALLS FROM

THE RH OUTBOARD ELEVON UPPER SURFACE JUST BEFORE THE COMPLETION OF THE ROLL MANEUVER. TRACKING IS LOST AFTER ROLL MANEUVER AND IS NOT REGAINED.

E-58
96 FPS
35mm

Camera is located at camera site 6 on the NW pad perimeter. Remote tracking of center one-third of launch vehicle from ignition to 1200 feet.

Focus : OK
F. O. V.: TRACKING IS ERRATIC
Exposure: OK

Comments: SEE COMMENTS FOR ITEM E-57.

E-59
96 FPS
35mm

Camera is located at camera site 6 on the NW pad perimeter. Remote tracking of upper one-third of launch vehicle from ignition to 1200 feet.

Focus : OK
F. O. V.: OK, EXCEPT FOR LOSS OF TRACKING
Exposure: OK

Comments: VAPORS EXIT GOX VENT LOUVER DURING SSME START-UP. VAPORS ALSO EMANATE FROM THE ET GH2 UMBILICAL CARRIER ASSEMBLY QD AFTER LIFTOFF. RCS PAPER COVERS ON FRCS ARE INTACT THROUGH LOV. NO TPS ANOMALIES ARE VISIBLE PRIOR TO LOV.

E-60
96 FPS
35mm

Camera is located on north pad perimeter at camera site 1 and views the entire launch vehicle, FSS, and MLP zero level.

Focus : OK
F. O. V.: OK
Exposure: OK

Comments: A BIRD IS FIRST VISIBLE ON THE LEFT SIDE OF THE FRAME HEADING NORTH AND PASSES EAST OF THE WATER TOWER (FRAME 41-00). THIS BIRD WAS NOT NEAR THE VEHICLE. RETRACTION AND LATCHBACK OF THE GH2 VENT ARM APPEARS NORMAL FROM THIS DISTANCE. CONDENSATE ON THE ET AFT DOME AND WATER FROM THE SRB STIFFENER RINGS VAPORIZES. ANOTHER BIRD IS VISIBLE HEADING EAST AS THE VEHICLE CLEARS THE TOWER. NO TPS ANOMALIES ARE VISIBLE THROUGH LOV.

E-61
96 FPS
35mm

Camera is located at camera site 2 on the east pad perimeter and views the launch vehicle, FSS, and MLP.

Focus : OK
F. O. V.: OK
Exposure: OK

Comments: SSME IGNITION APPEARS NORMAL. A BIRD IS HEADED NORTH JUST PRIOR TO T-0. VEHICLE "TWANG" MOTION IS NORMAL. AT T-0, TWO BIRDS PASS CLOSE TO THE CAMERA HEADED SOUTHEAST. SEVERAL PARTICLES RISE OUT OF THE SRB EXHAUST HOLE AND MOVE UPWARDS/NORTH AT A 45 DEGREE ANGLE (FRAME 64-00). ICE/FROST PARTICLES FALL FROM THE ET/ORBITER UMBILICALS. CONDENSATE ON THE ET AFT DOME AND WATER FROM THE SRB STIFFENER RINGS VAPORIZES. AS THE VEHICLE CLEARS THE TOWER, A BIRD FLIES SOUTHEAST AWAY FROM THE PAD (SAME BIRD AS SEEN IN E-60).

E-62
96 FPS
35mm

Camera is located on the SE pad perimeter at camera site 3 and views entire vehicle, FSS, and MLP.

Focus : OK
F. O. V.: OK
Exposure: OK

Comments: SSME IGNITION APPEARS NORMAL. ATMOSPHERIC WATER VAPOR VAPORIZES AROUND ALL SSME NOZZLES. RESIDUAL LO2 VAPORIZES DURING T-0 UMBILICAL RETRACTION. JUST AFTER T-0, APPROXIMATELY 10 PIECES OF THROAT PLUG MATERIAL RISE UP OUT OF THE RH SRB EXHAUST HOLE NEAR THE AFT SKIRT. THROUGH EARLY ASCENT, 6 PIECES OF ICE FALL FROM THE ET/ORBITER UMBILICALS AND TWO PIECES OF PAPER COVERS FALL FROM THE RCS STINGERS. THE PARTICLE THAT APPEARED TO PASS BY THE VERTICAL STABILIZER IN E-40 IS NOT VISIBLE IN THIS ITEM. THE PARTICLE WAS PROBABLY CLOSE TO THE E-40 CAMERA LENS. CONDENSATE ON THE ET AFT DOME AND WATER IN THE SRB STIFFENER RINGS VAPORIZES SHORTLY AFTER LIFTOFF.

E-63
96 FPS
35mm

Camera is located on SW pad perimeter at camera site 4 and views entire launch vehicle, FSS, and MLP.

Focus : OK
F. O. V.: OK
Exposure: OK

Comments: SSME IGNITION APPEARS NORMAL. MORE THAN TYPICAL QUANTITIES OF ATMOSPHERIC WATER VAPOR ARE PRESENT AROUND ALL SSME NOZZLES. RESIDUAL LH2 VAPORIZES DURING T-0 UMBILICAL DISCONNECT.

WATER FROM THE SRB STIFFENER RINGS VAPORIZES SHORTLY AFTER LIFT-OFF. NUMEROUS ICE PARTICLES FALL FROM THE ET/ORBITER UMBILICALS. FRCS PAPER COVERS ARE IN PLACE THROUGH TOWER CLEAR.

E-64
96 FPS
35mm

Camera is located on NW pad perimeter at camera site 6 and views entire launch vehicle, FSS, and MLP.

Focus : OK
F. O. V.: OK
Exposure: OK

Comments: MORE THAN TYPICAL QUANTITIES OF ATMOSPHERIC WATER VAPOR ARE PRESENT AROUND ALL SSME NOZZLES. GOX VENT ARM DELUGE WATER IS VISIBLE. SRB IGNITION OVERPRESSURE UPSURGE CAUSES WATER IN SOUND SUPPRESSION WATER TROUGHS TO GEYSER UPWARD. RESIDUAL LH2 VAPORIZES DURING T-0 UMBILICAL DISCONNECT. WATER VAPORIZES ON THE ET AFT DOME AND SRB STIFFENER RINGS.

E-76
96 FPS
35mm

Camera is located on SE pad perimeter at camera site 3 and views SSME engines #1 and #3 and the RH OMS engine nozzle.

Focus : OK
F. O. V.: OK
Exposure: OK

Comments: HYDROGEN LEAD PRECEDES SSME #1 IGNITION, WHICH OCCURS IN FRAME 13-00. ICE PARTICLES FROM THE T-0 UMBILICALS ARE PULLED INTO THE SSME EXHAUST BY ASPIRATION. AFT RCS PAPER COVERS TEAR AND FALL AT SSME IGNITION. SSME START-UP SEQUENCE APPEARS NORMAL. ATMOSPHERIC WATER VAPOR CONDENSES AROUND ALL SSME NOZZLES. RESIDUAL LO2 VAPORIZES DURING T-0 UMBILICAL RETRACTION. ICE PARTICLES FALL FROM THE ET/ORBITER UMBILICALS AND VAPORS TRAIL FROM THE ORBITER LO2 FLIGHT QD AS THE VEHICLE RISES.

E-77
96 FPS
35mm

Camera is located on SW pad perimeter at camera site 4 and views SSME engines #1 and #2 and the LH OMS engine nozzle.

Focus : OK
F. O. V.: OK
Exposure: OK

Comments: HYDROGEN LEAD PRECEDES SSME #1 IGNITION. ATMOSPHERIC WATER VAPOR CONDENSES AROUND ALL SSME NOZZLES. ICE PARTICLES FALL FROM BOTH ET/ORBITER UMBILICALS AND THE LH2 T-0 UMBILICAL. T-0 OCCURS IN FRAME 55-08. TYPICAL QUANTITIES OF INSTAFOAM, SRB THROAT PLUG, AND WATER TROUGH MATERIAL ARE EJECTED FROM THE RH

SRB EXHAUST HOLE AT IGNITION. WATER ON THE RH SRB AFT SKIRT VAPORIZES. RESIDUAL LO2 AND LH2 VAPORIZES DURING RETRACTION OF THE T-0 UMBILICALS AND IS PULLED AFT BY SSME ASPIRATION. TYPICAL QUANTITIES OF RCS PAPER COVERS FALL FROM THE VEHICLE DURING ENGINE START AND LIFTOFF. LO2 TSM DOOR APPEARS TO HAVE CLOSED PROPERLY. WATER CONDENSATE FALLS FROM THE SPLIT IN THE RUDDER SPEED BRAKE AS THE VEHICLE RISES.

E-201
30 FPS
70mm

UCS-9 IFLOT tracking of launch vehicle from ignition and early flight through LOV.

Focus : OK
F. O. V.: OK
Exposure: OK

Comments: CONDENSATE ON ET AFT DOME AND WATER FROM SRB STIFFENER RINGS VAPORIZE SHORTLY AFTER LIFTOFF. A WHITE PARTICLE FALLS FROM THE RH WINGTIP JUST BEFORE THE ROLL MANEUVER IS COMPLETE AND IS PROBABLY THE WHITE TILE/SCREED FOUND ON THE PAD. NUMEROUS PIECES OF RCS PAPER COVER FALL AFT OF THE VEHICLE. TWO FLASHES OCCUR IN THE SSME PLUME AFTER THE ROLL MANEUVER. LOCAL SUPERSONIC FLOW CONDENSATION APPEARS AS THE VEHICLE PASSES MAX Q. SRB SEPARATION IS NOMINAL AND CHUNKS OF PROPELLANT SLAP FALL FROM THE SRB PLUMES

E-202
30 FPS
70mm

U247L116 IFLOT tracking of launch vehicle from ignition and early flight through LOV.

Focus : GOOD DURING EARLY ASCENT. BECOMES SOFT DUE TO ATMOSPHERIC EFFECTS LATER IN FLIGHT.
F. O. V.: OK
Exposure: OK

Comments: A PIECE OF WHITE TILE/SCREED FALLS FROM THE RH OUTBOARD ELEVON UPPER SURFACE JUST BEFORE THE ROLL MANEUVER IS COMPLETE. DURING EARLY ASCENT, NUMEROUS PIECES OF RCS PAPER COVER FALL AFT OF THE VEHICLE.

E-203
30 FPS
70mm

UCS-16 IFLOT tracking of launch vehicle from ignition and early flight through LOV.

Focus : OK
F. O. V.: OK
Exposure: OVEREXPOSED

Comments: CONDENSATE ON ET AFT DOME AND WATER FROM SRB STIFFENER RINGS VAPORIZE SHORTLY AFTER LIFTOFF. A PIECE OF WHITE TILE/ SCREED FALLS FROM THE RH OUTBOARD ELEVON UPPER SURFACE JUST BEFORE THE ROLL MANEUVER IS COMPLETE. LOCAL SUPERSONIC FLOW CONDENSATION BECOMES VISIBLE AS THE VEHICLE PASSES THROUGH MAX Q. A PARTICLE, POSSIBLE A PIECE OF SRB PROPELLANT/INHIBITOR OR AFT SKIRT INSTAFOAM, FALLS OUT OF THE SRB PLUME AS THE PITCHES OVER IN THE ASCENT TRAJECTORY. CLOUDS OBSCURE THE VEHICLE LATER IN FLIGHT.

E-204
48 FPS
35mm

PAFB IGOR tracking of launch vehicle from acquisition to SRB separation. Tracks ET/ORB after SRB separation to LOV.

Focus : SOFT
F. O. V.: IMAGE INVERTED
Exposure: UNDEREXPOSED

Comments: VEHICLE DETAIL IS NOT DISCERNIBLE DUE TO SOFT IMAGE. NUMEROUS RCS PAPER PIECES FALL AFT OF THE VEHICLE. FLASH IN THE SSME PLUME APPEARS IN FRAME 59-02. PLUME RECIRCULATION EFFECT BEGINS IN FRAME 290-00. SRB SEPARATION OCCURS IN FRAME 361-09.

E-205
48 FPS
35mm

Shiloh IFLOT tracking of launch vehicle from acquisition to SRB separation. Tracks ET/ORB after SRB separation to LOV.

Focus : SOFT
F. O. V.: OK
Exposure: UNDEREXPOSED

Comments: ALTHOUGH NOT OBSCURED BY CLOUDS, VEHICLE DETAIL IS AFFECTED BY SOFT FOCUS DUE TO ATMOSPHERIC HAZE. SRB SEPARATION OCCURS IN FRAME 552-08. AFTER SRB SEPARATION, A GLOWING PARTICLE FALLS FROM THE RH SRB PLUME.

E-206
48 FPS
35mm

Melbourne Beach ROTI tracking of launch vehicle from acquisition to SRB separation. Tracks ET/ORB after SRB separation to LOV.

Focus : SOFT
F. O. V.: OK
Exposure: OK

Comments: VEHICLE DETAIL IS NOT DISCERNIBLE DUE TO SOFT FOCUS AND ATMOSPHERIC EFFECTS. PLUME RECIRCULATION EFFECT IS VISIBLE STARTING IN FRAME 264-00. SRB SEPARATION OCCURS IN FRAME 349-03. GOOD VIEW OF ET AND ORB AFTER SRB SEPARATION.

E-207 UCS-10 MIGOR tracking of launch vehicle from acquisition to SRB separation. Tracks ET/ORB after SRB separation to LOV.
96 FPS
35mm

Focus : OK
F. O. V.: OK
Exposure: OK

Comments: CONDENSATE ON THE ET AFT DOME AND WATER FROM THE SRB STIFFENER RINGS VAPORIZE SHORTLY AFTER LIFTOFF. NO SIGNIFICANT MOVEMENT OF THE BODY FLAP WAS VISIBLE EARLY IN FLIGHT. THE BODY FLAP WAS OBSCURED LATER BY THE SRB.

FRAME	EVENT
52-00	PIECE OF AFT RCS PAPER COVER
71-06	WHITE OBJECT APPEARS TO ORIGINATE FROM THE RH WING TIP AREA AND IS PROBABLY THE PIECE OF MISSING WHITE TILE
102-11	RCS PAPER COVERS FROM LH SIDE OF ORBITER
123-08	THREE PIECES OF RCS PAPER FALL FROM LH SIDE OF ORBITER
125-09	FLASH IN SSME #1 PLUME
126-13	PIECE OF RCS PAPER COVER APPEARS FROM BEHIND ORBITER
130-01	PIECE OF RCS PAPER COVER APPEARS FROM BEHIND ORBITER
131-09	TWO PIECES OF RCS PAPER APPEAR FROM BEHIND ORBITER
137-08	TWO PIECES OF PAPER COVER FROM THE FRCS
144-13	SEVERAL PIECES OF PAPER COVER FROM FRCS
152-10	ONE PIECE OF PAPER COVER FROM THE AFT RCS
170-15	FLASH IN SSME PLUME
178-12	FLASH IN SSME PLUME
192-06	FLASH IN SSME PLUME
210-02	FLASH IN SSME #1 PLUME
228-07	APPEARANCE OF LOCAL SUPERSONIC FLOW CONDENSATION
231-01	FLASH IN SSME #3 PLUME
250-05	FLASH IN SSME PLUME
282-05	FLASH IN SSME PLUME
383-10	PROPELLANT PARTICLE DROPS OUT OF RH SRB PLUME
391-14	NUMEROUS PROPELLANT PARTICLES FALL FROM PLUME
436-10	ONE PROPELLANT PARTICLE FALLS FROM PLUME
443-14	ONE PROPELLANT PARTICLE FALLS FROM PLUME
491-09	FIVE PARTICLES FALL OUT OF PLUME
495-08	ONE PARTICLE FALLS OUT OF PLUME
513-08	ONE PARTICLE FALLS OUT OF PLUME
742-10	TWO PARTICLES OF SLAG FALL OUT OF PLUME
753-08	SEVERAL PARTICLES OF SLAG FALL OUT OF PLUME
763-13	SRB SEPARATION APPEARS NOMINAL
846-00	HUNDREDS OF PIECES OF PROPELLANT/SLAG, SOME OF WHICH APPEAR QUITE LARGE

E-208
48 FPS
35mm

Cocoa Beach DOAMS tracking of launch vehicle from acquisition to SRB separation. Tracks ET/ORB after SRB separation to LOV.

Focus : SOFT DUE TO ATMOSPHERIC EFFECTS
F. O. V.: OK
Exposure: UNDEREXPOSED

Comments: VEHICLE DETAIL IS NOT DISCERNIBLE DUE TO ATMOSPHERIC HAZE/CLOUDS. SRB SEPARATION OCCURS IN FRAME 99-04.

E-209
30 FPS
70mm

SHILOH IFLOT intermediate tracking of launch vehicle from acquisition to LOV.

Focus : OK
F. O. V.: OK
Exposure: OK

Comments: SRB SEPARATION IS NOMINAL. PIECES OF SRB PROPELLANT SLAG FALL OUT OF THE SRB PLUMES AFTER SEPARATION.

E-210
30 FPS
70mm

UCS-26 IFLOT intermediate tracking of launch vehicle from acquisition to LOV.

Focus : OK
F. O. V.: OK
Exposure: OK

Comments: FEWER FLASHES IN THE SSME PLUME ARE VISIBLE DUE TO THE SLOWER FRAME RATE. CLOUDS OBSCURE THE VEHICLE EARLY IN THE ASCENT

E-211
96 FPS
35mm

UCS-13 IFLOT intermediate tracking of forward portion of ORB and ET from acquisition to LOV.

Focus : SOFT DUE TO ATMOSPHERIC EFFECTS
F. O. V.: OK
Exposure: OK

Comments: A WHITE TILE FRAGMENT FALLS FROM THE RH OUTBOARD ELEVON UPPER SURFACE IN FRAME 103-15. LOCAL SUPERSONIC FLOW CONDENSATION BECOMES VISIBLE ON THE SRB FORWARD ASSEMBLIES AT MAX Q. A LARGE PARTICLE OF SLAG FALLS FROM THE SRB AFT SKIRT AT SRB SEPARATION.

E-212 UCS-23 MIGOR tracking of launch vehicle from acquisition to LOV.
64 FPS
35mm

Focus : OK
F. O. V.: IMAGE IS INVERTED, POOR TRACKING
Exposure: SLIGHTLY UNDEREXPOSED

Comments: MOST OF THE ASCENT IS OBSCURED BY CLOUDS. A WHITE PARTICLE FALLS AFT OF THE SSME IN FRAME 27-03. TYPICAL SSME FLASHES AND PARTICLES ARE VISIBLE AS NOTED IN OTHER TRACKER ITEMS.

E-213 UCS-12 MOTS tracking of forward portion of ORB and ET from acquisition to LOV.
96 FPS
35mm

Focus : OK
F. O. V.: POOR TRACKING DURING INITIAL ASCENT
Exposure: UNDEREXPOSED

Comments: CONDENSATE ON THE ET AFT DOME AND WATER IN THE SRB STIFFENER RINGS VAPORIZES. A WHITE PARTICLE FALLS FROM THE FORWARD OUTBOARD CORNER OF THE RH OUTBOARD ELEVON UPPER SURFACE IN FRAME 108-13. THIS OBJECT IS MOST LIKELY THE WHITE TILE FRAGMENT FOUND AT THE PAD AFTER LAUNCH. NUMEROUS PIECES OF RCS PAPER FALL AFT OF THE VEHICLE AFTER COMPLETION OF ROLL MANEUVER. IN FRAME 179-09, A RH RCS PAPER COVER FALLS PAST THE VEHICLE. FLASHES APPEAR IN THE SSME PLUME IN FRAMES 157-03, 162-09, AND 269-04 (LARGEST FLASH). NO APPARENT BODY FLAP MOTION.

E-217 Beach Road IFLOT close-in tracking of launch vehicle during ignition, liftoff, and early portion of flight through LOV.
30 FPS
70mm

Focus : OK
F. O. V.: OK
Exposure: OK

Comments: CONDENSATE ON THE ET AFT DOME AND WATER FROM THE SRB STIFFENER RINGS VAPORIZE SHORTLY AFTER LAUNCH. A PIECE OF WHITE TILE/SCREED FALLS FROM THE RH OUTBOARD ELEVON UPPER SURFACE JUST BEFORE THE ROLL MANEUVER IS COMPLETE. NUMEROUS PIECES OF RCS PAPER COVERS FALL AFT OF THE VEHICLE AND INTO THE PLUME. FEWER FLASHES IN THE SSME PLUME ARE VISIBLE DUE TO THE SLOWER FRAME RATE.

E-218 UCS-26 IFLOT intermediate tracking of launch vehicle from acquisition through LOV.
96 FPS
35mm

Focus : SOFT DUE TO ATMOSPHERIC EFFECTS
F. O. V.: INCONSISTENT TRACKING
Exposure: OK

Comments: VEHICLE IS OBSCURED BY CLOUDS EXCEPT FOR EARLY ASCENT. CONDENSATE ON THE ET AFT DOME AND WATER IN THE SRB STIFFENER RINGS VAPORIZES. A LARGE WHITE PARTICLE, PERHAPS THE LOST TILE FRAGMENT OR A PIECE OF RCS PAPER COVER, APPEARS AFT OF THE VEHICLE IN FRAME 21-07. EIGHT PARTICLES OF RCS PAPER COVER FALL AND TWO FLASHES APPEAR IN THE SSME PLUME AFTER ROLL MANEUVER.

E-220 U247L116 IFLOT close-in tracking of forward portion of ORB and ET during ignition, liftoff, and early portion of flight through LOV.
96 FPS
35mm

Focus : OK
F. O. V.: POOR TRACKING DURING LATE ASCENT
Exposure: SLIGHTLY UNDEREXPOSED

Comments: CONDENSATE ON THE ET AFT DOME AND WATER IN THE SRB STIFFENER RINGS VAPORIZES. ICE PARTICLES FALL FROM THE ET/ORBITER AND THE T-0 UMBILICALS. ATMOSPHERIC WATER VAPOR CONDENSES AROUND THE SSME NOZZLES. A WHITE PARTICLE FALLS FROM THE RH WING JUST BEFORE THE COMPLETION OF THE ROLL MANEUVER. NUMEROUS RCS PAPER COVER PARTICLES FALL DURING EARLY ASCENT THROUGH ROLL MANEUVER. FLASHES OCCUR IN THE SSME #1 PLUME AT FR 124-02 AND 125-04. THESE FLASHES ARE USUALLY CAUSED BY PIECES OF RCS PAPER COVER BURNING IN THE SSME PLUME. A LARGER FLASH APPEARS IN SSME #1 PLUME IN FRAME 157-08. IN FRAME 163-02, AN RCS PAPER COVER ENTERS THE SSME PLUME AND A RED FLASH OCCURS.

E-222 Beach Road IFLOT close-in tracking of forward portion of ORB and ET during ignition, liftoff, and early portion of flight through LOV.
96 FPS
35mm

Focus : OK
F. O. V.: OK
Exposure: VERY UNDEREXPOSED

Comments: ICE PARTICLES FALL FROM THE ET/ORBITER UMBILICALS. A TYPICAL QUANTITY OF RCS BUTCHER PAPER COVERS FALL FROM THE VEHICLE DURING EARLY ASCENT. A WHITE PARTICLE FALLS FROM THE FORWARD OUTBOARD CORNER OF THE RH OUTBOARD ELEVON UPPER SURFACE INTO THE PLUME IN FRAME 98-00. THIS OBJECT IS MOST LIKELY THE

WHITE TILE FRAGMENT FOUND AT THE PAD AFTER LAUNCH. FLASHES IN SSME #1 PLUME OCCUR IN FRAME 114-11 AND 143-03. TWO MORE FLASHES OCCUR AS THE VEHICLE PASSES THROUGH A CLOUD LAYER AT FRAMES 244-05 AND 270-07.

E-223
96 FPS
35mm

UCS-9 IFLOT intermediate tracking of forward portion of ORB and ET during ignition, liftoff, and early portion of flight through LOV.

Focus : SOFT AND BLURRY
F. O. V.: OK
Exposure: OK

Comments: IN FRAME 99-12, A WHITE OBJECT APPEARS TO ORIGINATE FROM THE AREA OF THE RH WING TIP AND MAY BE THE MISSING PIECE OF TILE FROM THE RH OUTBOARD ELEVON. NUMEROUS FLASHES OCCUR IN THE SSME PLUME DURING ASCENT AT FRAMES 149-07, 155-01, 212-00, 228-09, 266-03, 281-00, AND 296-04. AFTER MAX Q, TWO PARTICLES FALL FROM THE RH SRB PLUME. THESE PARTICLES ARE USUALLY PIECES OF SRB PROPELLANT/INHIBITOR OR INSTAFOAM FROM THE AFT SKIRT. SIMILAR QUANTITIES OF RCS PAPER COVERS, PARTICLES DROPPING OUT OF THE SRB PLUMES, AND PIECES OF SLAG FALLING FROM THE SRB PLUMES AFTER SEPARATION ARE COMPARABLE TO FILM ITEM E-207.

E-233,234

Castglance aircraft tracks re-entry of SRB's, parachute deployment, and splashdown.

Comments: THESE FILM ITEMS WERE NOT RUN DUE TO AN AIRCRAFT PROBLEM.

E-310,302

On-board SRB cameras record parachute deployment. The cameras are located in the forward skirts.

Comments: DUE TO THE PREVIOUSLY PLANNED NIGHT LAUNCH, THESE CAMERAS WERE NOT INSTALLED FOR THIS MISSION.

VIDEO ITEMS

OTV 001 Views aft end of Orbiter from the FSS 255 foot level.
B/W M-II

Comments: WATER DELUGE FLOWS INTO SSME EXHAUST HOLE AND T-0 UMBILICAL CAMERA LIGHT INSIDE THE TSM IS ACTIVATED. DISCONNECT AND RETRACTION OF THE LH2 T-0 UMBILICAL IS NORMAL. RESIDUAL VAPORS FROM THE FLIGHT QD ARE DRAWN AFT INTO THE SSME PLUME BY ASPIRATION. SEVERAL PIECES OF WATER TROUGH MATERIAL ARE BLOWN OVER THE TOP OF THE TSM AFTER THE VEHICLE HAS CLEARED THE FOV.

OTV 003 Views GUCP and GH2 vent line.
B/W M-II

Comments: SPRAY FROM THE FSS WATER DELUGE BLOWS ACROSS THE FOV. VEHICLE 'TWANG' APPEARS NORMAL. DISCONNECT AND RETRACTION OF THE GUCP IS NOMINAL.

OTV 009 Views ET/Orbiter LH2 umbilical area from the 95 foot level of the FSS.
B/W M-II

Comments: PURGE VAPORS PRIOR TO SSME IGNITION ARE NORMAL. SPRAY FROM FSS WATER DELUGE CROSSES FOV. SSME IGNITION CAUSES A SHOWER OF ICE/FROST TO FALL FROM THE ET/ORB UMBILICALS, BUT NO LOWER SURFACE TILE DAMAGE IS VISIBLE. CONDENSATE/WATER SPRAY/VAPORS EXIT FROM THE ET/SRB -Y CABLE TRAY SPLICE. ICE CONTINUES TO FALL FROM THE UMBILICALS' AFTER LIFTOFF. ATMOSPHERIC WATER VAPOR VAPORIZES AROUND THE SSME NOZZLES.

OTV 041 Views and tracks vehicle from camera site 2.
B/W

Comments: SSME IGNITION APPEARS NORMAL. AFTER T-0, NO VEHICLE DETAIL IS DISCERNIBLE DUE TO EXPOSURE PROBLEMS.

OTV 043 Views east side of launch vehicle and pad from camera site 2.
B/W

Comments: CAMERA WAS POINTED AT THE HYDROGEN FLARE STACK FOR LAUNCH.

OTV 048 Launch and tracking view from camera site 6.
B/W

Comments: TRACKING IS ERRATIC. VEHICLE IS BACKLIT BY THE SUN. CONDENSATE ON ET AFT DOME AND WATER FROM SRB STIFFENER RINGS VAPORIZES.

OTV 049 Views Orbiter LO2 T-0 umbilical from MLP deck.
B/W M-II

Comments: DISCONNECT AND RETRACTION OF THE LO2 T-0 UMBILICAL IS NOMINAL. RESIDUAL VAPORS FROM THE FLIGHT QD ARE DRAWN AFT INTO THE SSME PLUME BY ASPIRATION.

OTV 050 Views Orbiter LH2 T-0 umbilical from MLP deck.
B/W M-II

Comments: SSME IGNITION CAUSES ICE/FROST PARTICLES TO SHAKE LOOSE AND FALL FROM THE LH2 T-0 UMBILICAL. DISCONNECT AND RETRACTION OF THE UMBILICAL IS NOMINAL. RESIDUAL VAPORS FROM THE FLIGHT QD ARE DRAWN AFT INTO THE SSME PLUME BY ASPIRATION.

OTV 051 Views main engine cluster.
B/W M-II

Comments: SSME IGNITION IS NOMINAL. RCS PAPER COVERS TEAR AND PIECES FALL INTO THE PLUME AFTER SSME IGNITION. RESIDUAL VAPORS FROM THE LO2 T-0 UMBILICAL ARE DRAWN INTO THE SSME PLUME BY ASPIRATION.

OTV 054 Views ET/Orbiter LO2 umbilical and Orbiter RH wing
B/W M-II

Comments: SSME IGNITION CAUSES A SHOWER OF ICE/FROST PARTICLES TO FALL FROM THE ET/ORB UMBILICALS, BUT NO LOWER SURFACE TILE DAMAGE IS VISIBLE. VEHICLE 'TWANG' IS APPARENT AS THE SSME'S THROTTLE UP. THE RH WING/ELEVONS SHAKE SLIGHTLY AT LIFTOFF. WATER VAPOR IN THE ATMOSPHERE VAPORIZES AROUND THE SSME NOZZLES.

OTV 055 Views RH SRB and underside of Orbiter RH wing.
B/W M-II

Comments: LITTLE DETAIL IS VISIBLE DUE TO UNDEREXPOSURE BY THE CAMERA AEC. SSME IGNITION CAUSES ICE/FROST PARTICLES TO SHAKE LOOSE AND FALL FROM THE ET/ORB LO2 UMBILICAL. AT T-0, WATER IN THE SOUND SUPPRESSION WATER TROUGHS GEYSERS UPWARD FROM THE OVER-PRESSURE WAVE IN THE FLAME TRENCH. WATER VAPOR IN THE ATMOSPHERE VAPORIZES AROUND THE SSME NOZZLES. NO SRB OR ET ANOMALIES.

OTV 056 Views LH SRB and underside of Orbiter LH wing.
B/W M-II

Comments: WATER SPRAY FROM THE FSS DELUGE IS BLOWN EASTWARD. PART OF THE VAPORS AT MLP DECK LEVEL IS EXHAUST FROM THE LH SRB HPU'S. LITTLE DETAIL IS VISIBLE DUE TO UNDEREXPOSURE BY THE CAMERA AEC. SSME IGNITION CAUSES ICE/FROST PARTICLES TO SHAKE LOOSE AND FALL FROM THE ET/ORB LH2 UMBILICAL. A WAVE OF CONDEN-SATE FROM THE ET AFT DOME FALLS AFTER SSME IGNITION. AT T-0, WATER IN THE SOUND SUPPRESSION WATER TROUGHS GEYSERS UPWARD FROM THE OVERPRESSURE WAVE IN THE FLAME TRENCH. NO SRB OR ET ANOMALIES

OTV 060 Views ET nosecone and NE louver from water tower.
Color M-II

Comments: A WALL OF WATER (CONDENSATE) FROM THE ET AFT DOME FALLS DURING SSME IGNITION. GH2 VENT ARM ROTATION AND LATCHBACK APPEAR NORMAL.

OTV 061 Views ET nosecone and SW louver from the FSS.
Color M-II

Comments: FOOTPRINT MARKINGS ARE VERY LIGHT IN THE UPPER RIGHT CORNER. FROST COATED THE LOUVERS, BUT NO ICEBALLS WERE PRESENT. TOPCOAT WAS MISSING FROM THE FOOTPRINT AREA IN FOUR PLACES (3 BELOW THE GRID AND 1 ON THE -Z SIDE OF THE LOUVER). LIGHT, RESIDUAL VAPORS EXITING THE LOUVER ARE BLOWN EASTWARD PAST THE NOSECONE FAIRING.

OTV 063 Views ET/Orbiter umbilical and Orbiter T-0
Color M-II umbilical from the FSS.

Comments: WATER DELUGE SPRAY FROM THE FSS PASSES IN FRONT OF CAMERA LENS. THE CAMERA LIGHT INSIDE THE LH2 TSM IS ACTIVATED AND ILLUMINATES THE T-0 CARRIER PLATE. A SHOWER OF ICE/FROST PARTICLES IS SHAKEN LOOSE FROM THE ET/ORB UMBILICALS BY SSME IGNITION, FALLS PAST THE BODY FLAP, AND IS PULLED INTO THE SSME EXHAUST HOLE BY ASPIRATION. NO TILE DAMAGE IS VISIBLE. LH2 T-0 UMBILICAL RETRACTION IS NOMINAL AND RESIDUAL VAPORS EMANATE FROM THE FLIGHT QD. CONDENSATE/SPRAY/VAPORS MOMENTARILY EXIT THE -Y ET/SRB CABLE TRAY SPLICE. CONDENSATE ON THE ET AFT DOME AND WATER FROM THE SRB STIFFENER RINGS VAPORIZE SHORTLY AFTER LIFTOFF.

OTV 070 Views overall vehicle from SE direction.
Color M-II

Comments: SSME IGNITION APPEARS NORMAL. RETRACTION OF THE LO2 T-0 UMBILICAL IS NORMAL AND A LARGE QUANTITY OF RESIDUAL VAPORS ARE PULLED INTO THE SSME PLUME BY ASPIRATION. ICE FALLS FROM THE MLP/FACILITY CRYOGENIC LINES. CONDENSATE ON THE ET AFT DOME AND WATER FROM THE SRB STIFFENER RINGS VAPORIZES SHORTLY AFTER LIFT-OFF. VERY LITTLE FACILITY DEBRIS WAS VISIBLE.

OTV 071 Views overall vehicle from SW direction.
Color M-II

Comments: HYDROGEN LEAD IS VISIBLE IN SSME #1 NOZZLE PRIOR TO IGNITION. SSME IGNITION APPEARS NORMAL AND ATMOSPHERIC WATER VAPOR VAPORIZES AROUND ALL SSME NOZZLES. RCS PAPER COVERS TEAR AND PIECES FALL INTO THE PLUME. ICE IS SHAKEN LOOSE FROM THE T-0 UMBILICALS DURING RETRACTION.

STI (C/S 2) Infrared view from camera site 2.
B/W M-II

Comments: THE IR SCANNER WAS NOT OPERATIONAL FOR THIS LAUNCH.

STI (RSS) Infrared view from RSS roof.
B/W M-II

Comments: SSME START UP SEQUENCE IS CLEARLY VISIBLE. SOME FREE BURNING HYDROGEN RISES UPWARD TO ORBITER BASE HEATSHIELD NEAR SSME #1 DURING IGNITION. SSME THROTTLE UP AND THERMAL GRADIENTS APPEAR NORMAL.

TV-2 Views launch from the SLF.
Color M-II

Comments: VIEW IS TOO DISTANT FOR DETAIL. NO VEHICLE ANOMALIES.

TV-3 Views entire launch vehicle from camera site 9
Color M-II

Comments: VIEW IS TOO DISTANT FOR DETAIL. NO VEHICLE ANOMALIES.

TV-4 Views entire vehicle from Beach Road IFLOT Site.
Color M-II

Comments: CAMERA SHAKE AND SOFT FOCUS DETRACT FROM IMAGE DETAIL. SSME IGNITION APPEARS NORMAL. JUST BEFORE THE END OF THE ROLL MANEUVER, A PIECE OF WHITE TILE/SCREED FALLS FROM THE RH OUTBOARD ELEVON UPPER SURFACE. VERY LITTLE OVERSHOOT ON THE ROLL MANEUVER. CONDENSATE ON ET AFT DOME AND WATER FROM SRB STIFFENER RINGS VAPORIZE. CLOUDS OBSCURE MOST OF THE ASCENT. A FLASH IN THE SSME PLUME OCCURS AS THE VEHICLE PASSES THROUGH A THIN CLOUD LAYER.

TV-5 Views launch from VAB roof.
Color M-II

Comments: EARLY VIEW OF THE VEHICLE IS DISTANT AND HAZY. LOCAL SUPERSONIC FLOW CONDENSATION BECOMES VISIBLE AT T+44 SECONDS. AT T+83 SECONDS, A PARTICLE FALLS OUT OF THE LH SRB PLUME. THIS OBJECT IS SIMILAR TO CHUNKS OR SRB PROPELLANT/INHIBITOR OR AFT SKIRT INSTAFOAM OBSERVED ON PREVIOUS LAUNCHES. SRB SEPARATION IS NOMINAL. SEVERAL LARGE PIECES OF SRB PROPELLANT SLAG FALL FROM THE RH SRB PLUME AT T+134 SECONDS.

TV-7 Views entire launch vehicle from camera site 2
Color M-II east of pad.

Comments: IMAGE IS OVEREXPOSED. SSME IGNITION APPEARS NORMAL. CONDENSATE ON THE ET AFT DOME AND WATER FROM THE SRB STIFFENER RINGS VAPORIZE SHORTLY AFTER LIFTOFF. VERY LITTLE FACILITY DEBRIS IS VISIBLE.

TV-11 Views launch from SLF TV Tower #1.
Color M-II

Comments: IMAGE IS OVEREXPOSED. VIEW IS TOO DISTANT FOR DETAIL.

TV-13 Cocoa Beach DOAMS video. Tracks launch vehicle
Color M-II from acquisition to LOV.

Comments: VIEW IS HAZY AND CLOUDY. TRACKING IS ERRATIC. SRB SEPARATION APPEARS NOMINAL. FAIRLY GOOD DETAIL IS VISIBLE ON THE ET AFTER SRB SEPARATION INCLUDING THE LONGERON NEAR THE 2058 RING - NO ANOMALIES.

TV-16 View from helicopter orbiting west of pad and VAB.
Color M-II

Comments: VIEW IS TOO DISTANT FOR DETAIL. NO VEHICLE ANOMALIES.

TV-18 Malabar ITEC video. Tracks launch vehicle from
Color M-II acquisition to LOV.

Comments: VIEW IS REVERSED DUE TO OPTICS. PLUME RECIRCULATION IS NORMAL. SRB SEPARATION IS NOMINAL EXCEPT AFT BSM'S APPEARS TO FIRE BEFORE FORWARD BSM'S BY ONE VIDEO FRAME. ET OGIVE AREA IS CHARRED FROM BSM FIRING. SOME DETAIL ON THE ET, SUCH AS THE LONGERON NEAR THE 2058 RING, IS VISIBLE, BUT NO ANOMALIES ARE APPARENT.

TV-21 Views entire launch vehicle from DLTR-3 site
Color M-II directly south of Pad B.

Comments: SEVERAL BIRDS EXIT FOV DURING SSME START-UP. IGNITION APPEARS NORMAL. LIFTOFF IS OBSCURED BY PLUME. CONDENSATE ON ET AFT DOME AND WATER FROM SRB STIFFENER RINGS VAPORIZES. ROLL MANEUVER IS NORMAL WITH VERY LITTLE OVERSHOOT. JUST AFTER THE ROLL PROGRAM, A BIRD CROSSES THE FOV, BUT DOES NOT APPEAR TO BE CLOSE TO THE VEHICLE. SRB SEPARATION IS OBSCURED BY CLOUDS.

ET-204 Patrick IGOR video. Tracks launch vehicle from
Color M-II acquisition to LOV.

Comments: SRB SEPARATION APPEARS NOMINAL THOUGH AFT BSM'S APPEAR TO FIRE ONE VIDEO FRAME BEFORE THE FORWARD BSM'S. PIECES OF SRB PROPELLANT SLAG ARE VISIBLE IN THE SRB PLUMES AT TAILOFF AND SEPARATION.

ET-206 Melbourne Beach ROTI video. Tracks launch vehicle
Color M-II from acquisition to LOV.

Comments: SOME PIECES OF RCS PAPER COVERS FALL AFT OF THE VEHICLE DURING EARLY ASCENT. PLUME RECIRCULATION IS NORMAL. SRB SEPARATION IS NOMINAL. POST SEPARATION VIEWS OF THE ORB/ET ARE FAIRLY GOOD AND LARGE FEATURES ON THE ET, SUCH AS THE LONGERON AND INTERTANK FLANGES, ARE VISIBLE.

ET-207 UCS-10 MIGOR video. Tracks launch vehicle from
Color M-II acquisition to LOV.

Comments: SEVERAL BIRDS CROSS THE FOV, BUT ARE NOT NEAR THE VEHICLE. IGNITION AND LIFTOFF ARE NORMAL. CONDENSATE ON THE ET AFT DOME AND WATER FROM THE SRB STIFFENER RINGS VAPORIZES SHORTLY AFTER LIFTOFF. THE PIECE OF WHITE TILE/SCREED FROM THE RH OUTBOARD ELEVON UPPER SURFACE FALLS FROM THE VEHICLE JUST BEFORE THE COMPLETION OF THE ROLL MANEUVER. NUMEROUS PIECES OF RCS PAPER COVER FALL AFT INTO THE SSME PLUME. LOCAL SUPERSONIC FLOW CONDENSATION BECOMES VISIBLE NEAR MAX Q AND IS A NORMAL EVENT. JUST BEFORE SRB SEPARATION, SEVERAL PIECES OF SRB PROPELLANT/INHIBITOR /SLAG FALL OUT OF THE PLUME. SRB SEPARATION IS NOMINAL. AFTER SEP, HUNDREDS OF PIECES OF SLAG, SOME OF WHICH ARE QUITE LARGE, FALL FROM THE SRB'S. THIS IS A NORMAL AND EXPECTED EVENT.

ET-208 Cocoa Beach DOAMS video. Tracks launch vehicle
Color M-II from acquisition to LOV.

Comments: ACQUISITION WAS LATE, POSSIBLY DUE TO CLOUDS AND HAZE. SRB SEPARATION IS NORMAL BUT AFT BSM'S APPEAR TO FIRE TWO VIDEO FRAMES BEFORE FORWARD BSM'S.

ET-212 UCS-23 MIGOR video. Tracks launch vehicle from
Color M-II acquisition to LOV.

Comments: PIECE OF WHITE TILE/SCREED FROM RH OUTBOARD ELEVON FALLS FROM VEHICLE JUST BEFORE COMPLETION OF ROLL MANEUVER. MOST OF ASCENT AND SRB SEPARATION IS OBSCURED BY CLOUDS.

ET-213 UCS-7 MOTS video. Tracks launch vehicle from
Color M-II acquisition to LOV.

Comments: SSME IGNITION IS NOMINAL. T-0 AND LIFTOFF OCCURS AT GMT 12:35:00. ROLL MANEUVER IS COMPLETE AT APPROXIMATELY T+16 SECONDS. VERY LITTLE DETAIL IS VISIBLE ON THE VEHICLE DUE TO EXPOSURE PROBLEMS.

7.2 ON-ORBIT FILM DATA REVIEW

UMB CAM Camera is in the Orbiter LH2 umbilical and views 16mm SRB and ET separation with a 10mm lens

Comments: A PIECE OF HYDROGEN FIRE DETECTION BUTCHER PAPER WAS STILL ATTACHED TO THE VEHICLE. EROSION ON THE LH2 UMBILICAL AND ET/SRB CABE TRAYS AND NORMAL 'POPCORNING' ON THE ACREAGE HAD OCCURRED. SRB SEPARATION WAS NOMINAL. THE LH ET/SRB UPPER STRUT SEPARATED CLEANLY WHEN THE ORDNANCE FIRED, BUT THE STRUT ENDS RECONTACTED MOMENTARILY AS THE SRB MOVED AWAY. ICE FELL FROM THE STRUT FAIRING DURING AND AFTER SEPARATION.

AS THE LH2 UMBILICAL CARRIER PLATES SEPARATED, RESIDUAL HYDROGEN EXITED THE CAVITY BETWEEN THE 17-INCH VALVES. SOME OF THIS HYDROGEN FROZE AND CHUNKS DRIFTED BY THE CAMERA. NUMEROUS SMALL PIECES OF ET TPS WERE MIXED IN WITH THE FROZEN PARTICLES. FOUR LARGE PIECES OF FOAM, CHARACTERIZED BY THE DARKER BROWN RIND ON ONE SIDE, DIVOT SHAPED EDGES, KNIT LINES, AND ISOCHEM LAYER, AP-PEARED FROM BEHIND THE UMBILICAL CABLE TRAY OR FELL AFT INTO THE FOV. THESE FOAM PIECES ARE THE DIVOTS FROM THE INTERTANK AREA. FROZEN HYDROGEN CONTINUED TO MOVE THROUGH THE FOV, SOME OF WHICH IMPACTED THE ET AT THE 2058 RING AND BROKE APART.

ET SEPARATION WAS NOMINAL AND THE CONDITION OF THE TANK WAS EXCELLENT. NO ANOMALIES WERE VISIBLE ON THE OGIVE/NOSECONE. CHAR-RING FROM AERO HEATING WAS NORMAL. THERE WERE NO DIVOTS OR AREAS OF MISSING ABLATOR VISIBLE, NOR WAS THERE METAL SHOWING IN THE BSM BURN SCAR. LIKEWISE, THE ACREAGE OF THE INTERTANK WAS INTACT EXCEPT FOR FIVE LARGE DIVOTS IN THE AREA OF THE BIPODS. THERE WERE NO DIVOTS ON THE INTERTANK-TO-LH2 AND LO2 TANK FLANGES.

THE LH2 TANK ACREAGE WAS IN GOOD CONDITION WITH THE EXCEPTION OF 2 DIVOTS, ONE OF WHICH WAS A REPAIR, IN THE SPRAY ABORT AREAS. NO ANOMALIES WERE VISIBLE ON THE LO2 FEEDLINE OR LH2 TANK AFT DOME. VERY LITTLE CHARRING HAD OCCURRED IN THIS AREA. THE THRUST STRUTS, CROSSBEAM, AND AFT DOME SHOWED NORMAL ASCENT HEATING EFFECTS. FROZEN HYDROGEN FILLED THE ET LH2 UMBILICAL 17-INCH LINE AND SOME FOAM WAS MISSING FROM THE CABLE TRAY. THE TOP OF THE LH2 UMBILICAL WAS DAMAGED AND COVERED WITH FROZEN HYDROGEN.

UMB CAM Camera is in the Orbiter LH2 umbilical and views 16mm SRB and ET separation with a 5mm lens

Comments: A PIECE OF HYDROGEN FIRE DETECTION BUTCHER PAPER WAS STILL ATTACHED TO THE ET UMBILICAL CABLE TRAY. A PIECE OF FOAM WAS MISSING FROM THE OUTBOARD SIDE OF THE LH2 UMBILICAL CABLE TRAY. BUBBLES/BLISTERS IN THE FIRE BARRIER PAINT ON THE OUTBOARD SIDE OF THE UMBILICAL RIPPLED IN THE AIR STREAM. TPS ON THE ET LH2 TANK AFT DOME WAS OUTGASSING AND SMALL FOAM PARTICLES WERE

CAUGHT IN THE PLUME RECIRCULATION. A LARGE PIECE OF FOAM FELL AFT, STRUCK THE VEHICLE SOMEWHERE ABOVE THE CAMERA, AND BROKE INTO TWO PIECES. SRB SEPARATION WAS NOMINAL. THE LH ET/SRB UPPER STRUT SEPARATED CLEANLY, THOUGH THE STRUT HALVES LATER RECONTACTED MOMENTARILY AS THE SRB MOVED AWAY. ICE FELL OUT OF THE STRUT FAIRING DURING AND AFTER SEPARATION.

A PIECE OF FOAM MISSING FROM THE FORWARD OUTBOARD SIDE OF THE LH2 UMBILICAL CABLE TRAY WAS APPARENT AS THE UMBILICAL CAMERA WAS REACTIVATED FOR ET SEPARATION. MOVEMENT OF THE ET AWAY FROM THE ORBITER WAS NORMAL. BUBBLES/BLISTERS WERE VISIBLE IN THE FIRE BARRIER PAINT ON THE SIDE OF THE UMBILICAL. THE 17-INCH LINE/VALVE WAS FILLED WITH FROZEN HYDROGEN. THE TOP OF THE UMBILICAL WAS DAMAGED AND COVERED WITH FROZEN HYDROGEN. TWO LARGE LONGITUDINAL STREAKS ON THE LH2 TANK ACREAGE WERE PRESENT BEFORE LAUNCH AND OCCURRED DURING MANUFACTURING. THE FIVE RADIAL BANDS WERE CAUSED BY ABORTS DURING THE TPS SPRAYING OPERATION. ALTHOUGH THE LO2 TANK WAS CHARRED FROM ASCENT AERO HEATING, NO ANOMALIES WERE VISIBLE.

UMB CAM Camera is in the Orbiter LO2 umbilical and views
35mm ET separation

Comments: A TOTAL OF 62 FRAMES WERE EXPOSED ON THIS FILM ITEM. THE LO2 ET/ORB UMBILICAL WAS IN GOOD CONDITION WITH THE EXCEPTION OF ICE OR A THIN LAYER OF TPS PEELED BACK ON TOP OF THE UMBILICAL. NO ICE WAS VISIBLE IN THE 17-INCH LINE/VALVE. NO ANOMALIES WERE EVIDENT ON THE LO2 FEEDLINE. ICE WAS STILL PRESENT IN BOTH OF THE LOWER FEEDLINE BELLOWS.

THE LH2 TANK ACREAGE EXHIBITED TWO DIVOTS, ONE OF WHICH WAS A TPS REPAIR. THE TWO LONGITUDINAL STREAKS WERE PRESENT PRIOR TO LAUNCH AND OCCURRED DURING MANUFACTURING. SIMILARLY, THE FIVE RADIAL BANDS WERE ABORTS DURING THE TPS SPRAYING OPERATION. OTHER LIGHT-COLORED SPOTS ARE AREAS WHERE THE TPS SURFACE RIND HAD BEEN SANDED.

OVERALL, THE LO2 TANK ACREAGE AREA WAS IN GOOD CONDITION AND NO ANOMALIES WERE VISIBLE.

AN IFA WAS GENERATED AGAINST DIVOTS ON THE INTERTANK IN THE BIPOD AREA. TWO DIVOTS MEASURING 12-14 INCHES IN DIAMETER WERE LOCATED BETWEEN THE BIPODS AND JUST ABOVE THE INTERTANK-TO-LH2 TANK FLANGE. A THIRD DIVOT 14 INCHES IN DIAMETER WAS CENTERED BETWEEN THE BIPOD RAMPS AND EXTENDED INTO THE INTERTANK-TO-LH2 TANK FLANGE. THE LARGEST DIVOT, MEASURING 28 INCHES WIDE, SURROUNDED THE FORWARD PART OF THE LH BIPOD RAMP. STRINGERS WERE VISIBLE IN THE LARGE DIVOTS INDICATING A DEPTH GREATER THAN THE ISOCHEM LINE. A FIFTH DIVOT MEASURING 6 INCHES IN DIAMETER WAS LOCATED OUTBOARD OF THE LH BIPOD RAMP AND JUST ABOVE THE INTERTANK-TO-LH2 TANK FLANGE.

7.3 LANDING FILM DATA REVIEW

E-1001 Orbiter landing at Ames-Dryden Flight Research Facility
16mm

Comments: RH MLG WHEEL CONTACTS THE RUNWAY FIRST. THE ORBITER DISAPPEARS FROM VIEW AS IT MOVES OUT OF THE XENON LIGHTS. NOSE WHEEL TOUCHDOWN AND ROLLOUT CANNOT BE SEEN.

E-1002 Orbiter landing at Ames-Dryden Flight Research Facility
16mm

Comments: RH MLG WHEEL CONTACTS THE RUNWAY BEFORE THE LH MLG WHEEL. THE ORBITER DISAPPEARS FROM VIEW AS IT MOVES AWAY FROM THE XENON LIGHTS. NOSE WHEEL TOUCHDOWN AND ROLLOUT CANNOT BE SEEN.

E-1005 Orbiter landing at Ames-Dryden Flight Research Facility
35mm

Comments: FILM ITEM DID NOT RUN.

E-1006 Orbiter landing at Ames-Dryden Flight Research Facility
35mm

Comments: THIS WAS THE BEST VIEW OF LANDING. RH MLG WHEEL CONTACTS THE RUNWAY BEFORE THE LEFT MLG WHEEL. CONDENSATION IS VISIBLE IN BOTH WINGTIP VORTICES. THE ORBITER DISAPPEARS AS IT MOVES OUT OF THE XENON LIGHTS. NOSE WHEEL TOUCHDOWN AND ROLLOUT ARE NOT VISIBLE.

E-1008 Orbiter landing at Ames-Dryden Flight Research Facility
35mm

Comments: FILM ITEM NOT RUN.

E-1009 Orbiter landing at Ames-Dryden Flight Research Facility
16mm

Comments: DUE TO CAMERA POSITION AND NIGHT CONDITIONS, NO DETAIL WAS VISIBLE.

E-1011 Orbiter landing at Ames-Dryden Flight Research Facility
16mm

Comments: CONDENSATION IS VISIBLE IN BOTH WINGTIP VORTICES. RH MLG WHEEL CONTACTS THE RUNWAY BEFORE THE LEFT WHEEL. THE ORBITER DISAPPEARS FROM VIEW AS IT MOVES AWAY FROM THE XENON LIGHTS. NOSE WHEEL TOUCHDOWN AND VEHICLE ROLLOUT ARE NOT VISIBLE.

E-1012 Orbiter landing at Ames-Dryden Flight Research Facility
16mm

Comments: SAME AS E-1011.

8.0 SRB POST FLIGHT/RETRIEVAL DEBRIS ASSESSMENT

Both Solid Rocket Boosters were inspected for debris damage and debris sources at CCAFS Hangar AF on 11 January 1990 from 0800 to 1130 hours. In general, the SRB's appeared to be in good condition.

8.1 RH SOLID ROCKET BOOSTER DEBRIS INSPECTION

The nose cap was not recovered. The RH frustum was missing no MSA-2 TPS but exhibited 5 debonds over the bolt heads and one 1.75 inch diameter acreage debond. The Hypalon paint had blistered slightly only in localized areas (Figure 14). Some layers of MSA adhered to the paint. The four BSM aero heatshield covers were intact and properly locked in the 180 degree open position.

The RH Forward Skirt exhibited no debonds or missing TPS. Some layers of MSA adhered to the blistered Hypalon paint forward of the attach fitting. One layer of the phenolic plate had delaminated on the +Z RSS antenna and some of the material was missing (Figure 15). Separation of the forward attach fitting was nominal and the RSS cables separated cleanly. K5NA closeouts had been accomplished for this flight on the inboard corners of the RSS interface cable tray.

All field joint closeouts were undamaged. Known void areas on the field joint closeouts and repairs remained intact. The forward field joint had a 2-inch diameter bulge at the 185 degree radial location 2.5 inches aft of the forward edge. Minor trailing edge damage to the GEI cork runs was attributed to debris hits from nozzle extension severance.

The PDL pour on the aft side of the IEA was missing and the bolt head underneath was sooted. The +Y IEA end cover aft outboard corner was broken off. A bolt head on the adjacent cover was broken off and the RTV interface was cracked. Separation of the aft ET/SRB struts was nominal, though two electrical connectors on the upper strut were broken. The EPDM cover was torn around the upper strut and a cover bolt was missing near the aft side of the strut in the area of the missing EPDM.

The K5NA was cracked on the forward stiffener ring at the 135-150 degree location. K5NA was cracked (110-150 degrees) and the web broken (145 degrees) on the center stiffener ring. Some Instafoam was lost from the stiffener rings at splashdown.

The phenolic material on the kick ring delaminated in several locations. Two K5NA thermal protective domes were missing from bolt heads on the aft side of the kick ring at 260 degrees and the uncovered areas showed signs of heating prior to water impact. K5NA was also missing from all four aft BSM nozzles.

FIGURE 14. RIGHT SRB FRUSTUM

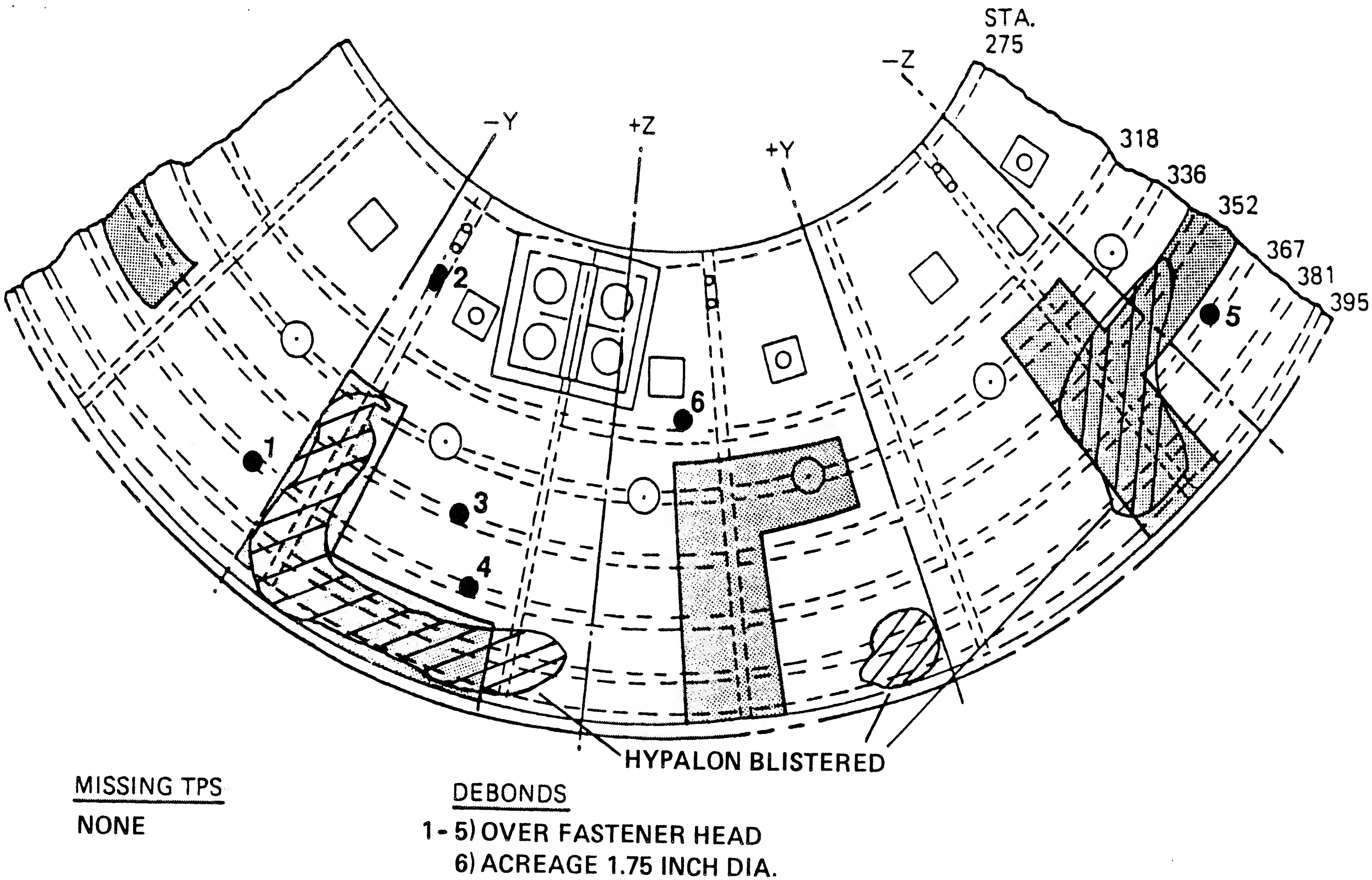
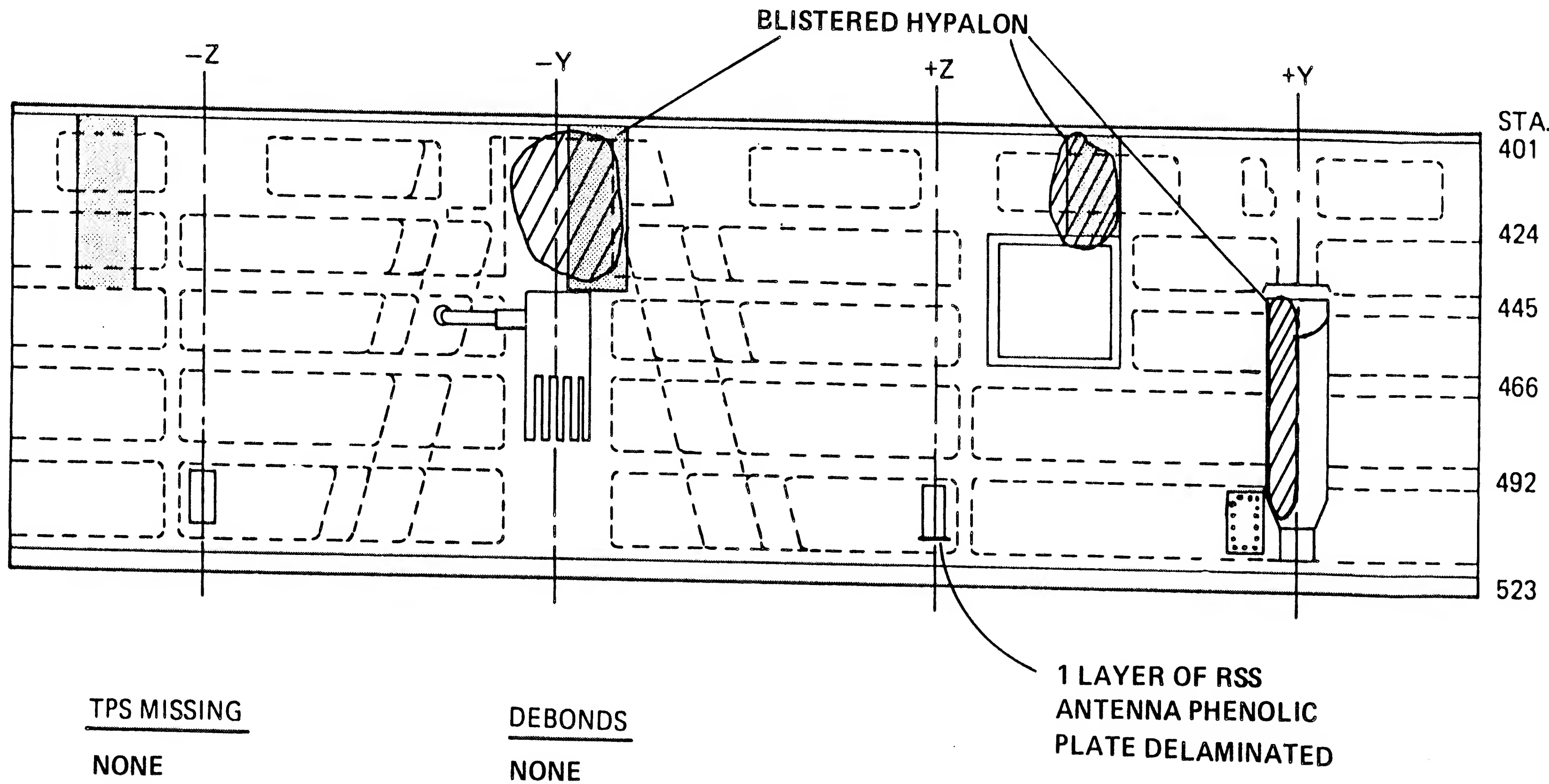


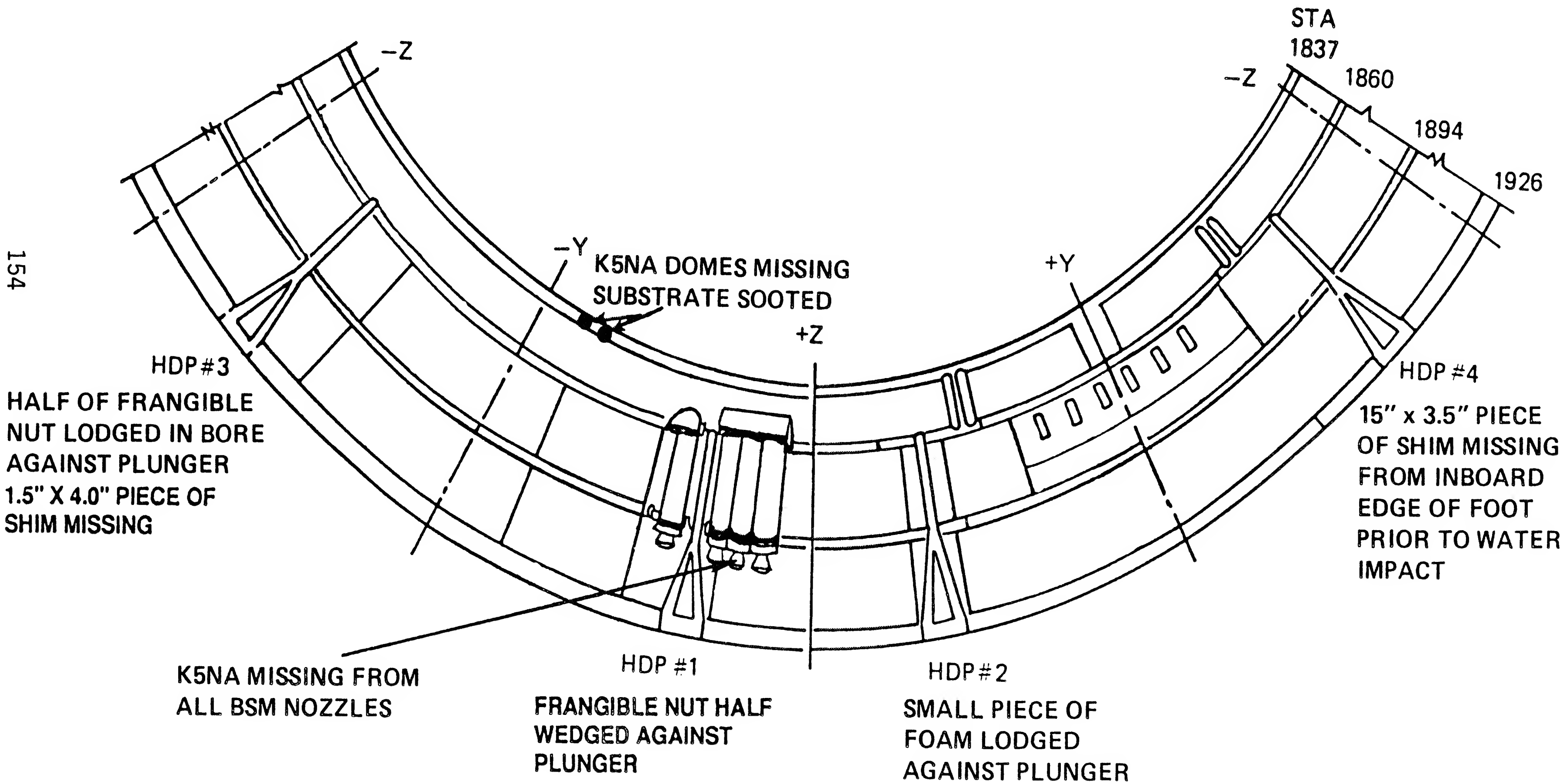
FIGURE 15. RIGHT SRB FWD SKIRT



The TPS over the aft skirt acreage was generally in good condition (Figure 16). The TVC system appeared to be undamaged. Instafoam was missing from the aft ring around the aft skirt feet, HPU exhaust horns, and joint heater umbilical.

Holddown post #1 plunger was not seated and a frangible nut half was wedged between the plunger and the spherical washer. A small piece of foam was lodged against the plunger in HDP #2 bore. HDP #3 plunger was not seated and half of the frangible nut was jammed in the bore against the plunger. The spherical washer was displaced. A 1.5"x4" section of shim was missing with substrate sooting. HDP #4 plunger was seated on a displaced spherical washer. A 15"x3.5" piece of the shim was missing from the inboard edge of HDP #4 aft skirt foot prior to water impact.

FIGURE 16. RIGHT SRB AFT SKIRT EXTERIOR TPS



EGG/V 326C

8.2 LH SOLID ROCKET BOOSTER DEBRIS INSPECTION

The nose cap was not recovered. The LH frustum exhibited 23 debonds over bolt heads and one 2-inch divot near the 275 ring. There was minor blistering of the Hypalon paint in localized areas (Figure 17). The BSM aero heatshield covers were intact and properly locked in the 180 degree open position.

The LH Forward Skirt exhibited no debonds or missing TPS (Figure 18). Hypalon paint was slightly blistered near the forward ET/SRB thrust post. The phenolic plate on the +Z RSS antenna was delaminated. Some of the phenolic material and silicone was missing. Separation of the forward attach fitting was nominal and the RSS cables separated cleanly. K5NA closeouts had been accomplished properly on the inboard corners of the interface cable tray.

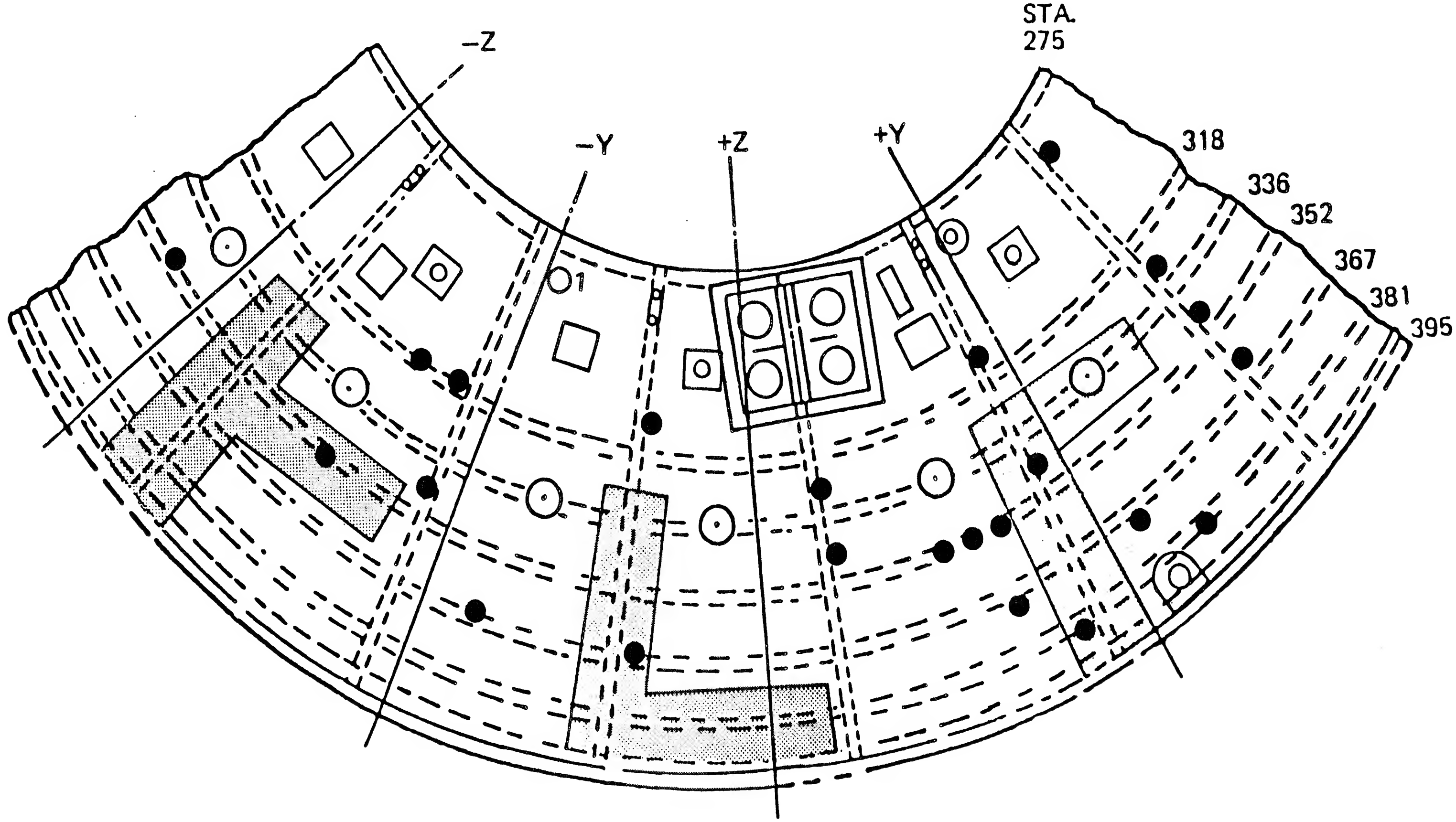
The field joint closeouts were undamaged and known void areas in the field joint closeouts were still intact. Trailing edge damage to the GEI cork runs was attributed to debris hits from the nozzle extension severance.

K5NA closeouts on the IEA covers were intact, but the Hypalon paint exhibited some blistering. PDL pours at the aft IEA bracket bolt locations came out prior to water impact. Some TPS was missing from the ETA ring. Separation of the aft ET/SRB struts was nominal. K5NA on the forward stiffener ring and foam on the center and aft stiffener rings were cracked due to water impact. The aft segment stiffener/stiffener factory joint EPDM moisture seal was debonded on the leading edge at 230 degrees (3.5" long by 1" deep) and 280 degrees (3" long by 1.25" deep).

The phenolic material on the kick ring delaminated in several locations. Some of the K5NA thermal protective domes came loose after water impact. K5NA was missing from all four aft BSM nozzles (Figure 19).

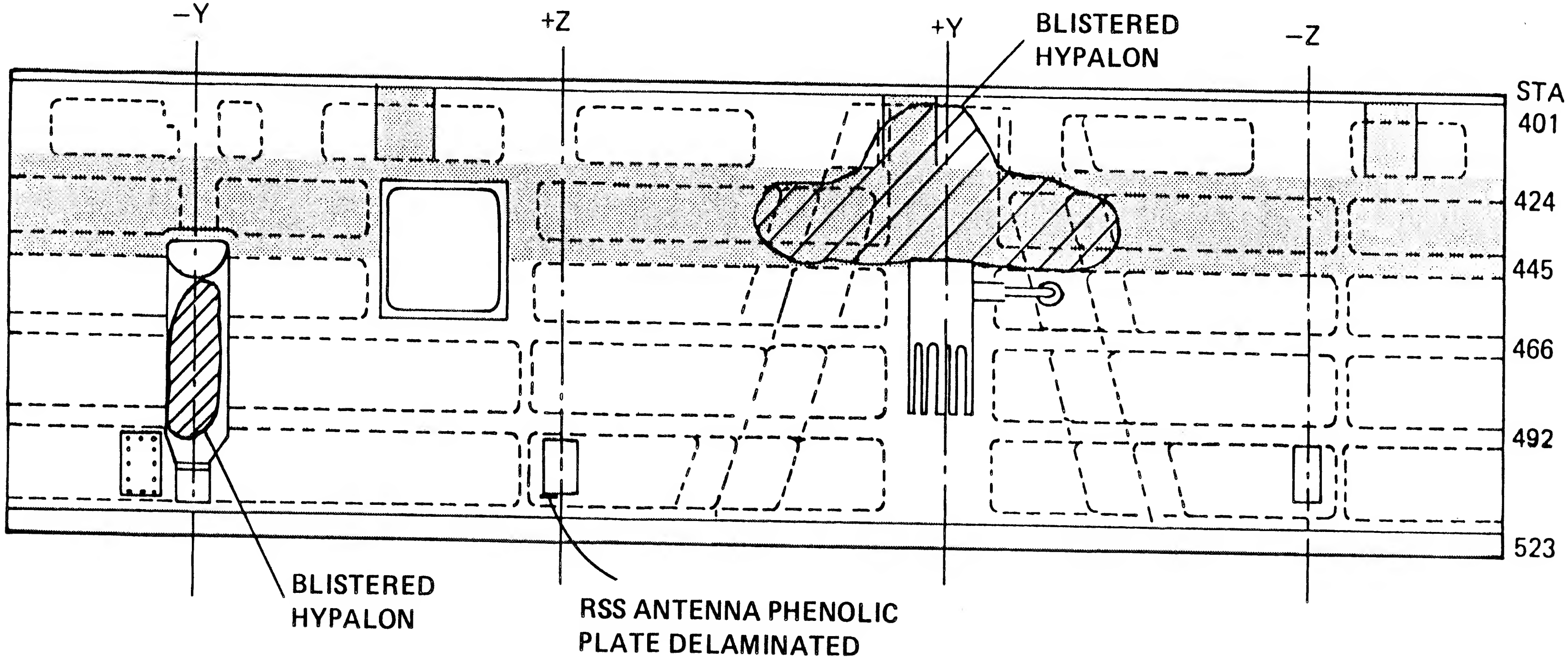
The HDP #5 and #6 plungers were seated, but the spherical washers were offset. The HDP #7 plunger was not seated and the spherical washer was displaced. Debris chunks were jammed against the plunger and one loose piece of debris (1"x1/2"x1/4") lay in the bore. A piece of thermal curtain was caught between the HDP #8 seated plunger and the spherical washer. This probably occurred during water impact, but the plunger would not have been latched.

FIGURE 17. LEFT SRB FRUSTUM



MISSING TPS	DEBONDS
1) 2-INCH DIVOT	23

FIGURE 18. LEFT SRB FWD SKIRT



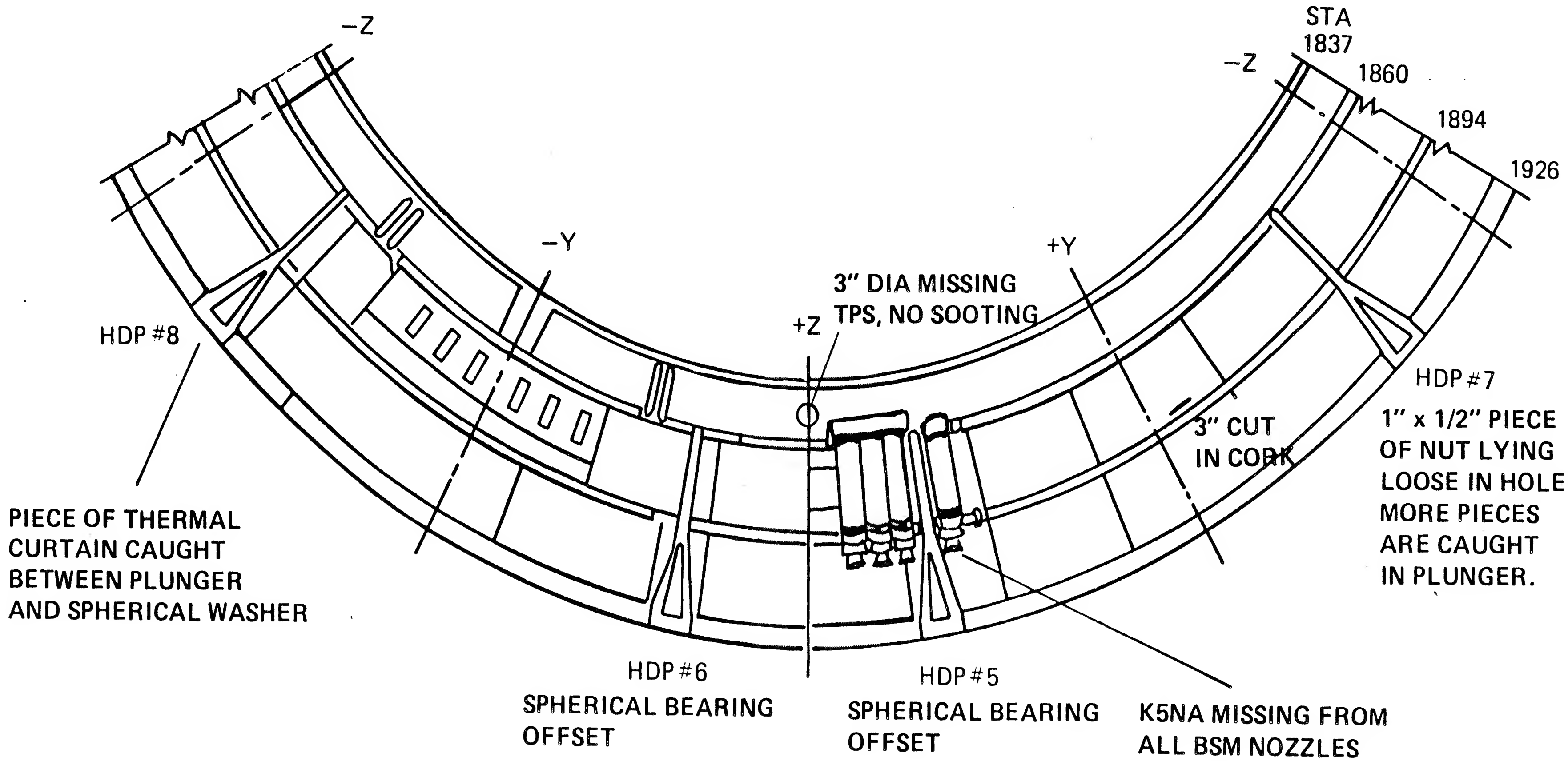
TPS MISSING

NONE

DEBONDS

NONE

FIGURE 19. LEFT SRB AFT SKIRT EXTERIOR TPS



8.3 RECOVERED SRB DISASSEMBLY FINDINGS

Assessment of the STS-32R booster set disclosed no major problems with the solid rocket motors or the USBI hardware. Water impact damage was minimal.

Water intrusion into the forward skirts has not been improved significantly by the design change to apply sealant on the separation bolt cover and around the flight door. The dome seal is the most likely source of the water intrusion.

A possible design deficiency of long standing was identified at the thermal curtain to nozzle compliance ring interface. The attach structure is stepped and does not fit flat against the compliance ring. USBI will perform an evaluation and determine a design change. The compliance ring helicoils backed out farther than on previous flights. Thiokol will investigate this problem.

EPDM and white ablator on the LH and RH upper strut covers was missing and could indicate the development of a hot gas path. Although this problem has occurred previously, it could not be pinpointed to re-entry.

Protruding bolts on the RH ET attach ring prevented the RTV on the RH IEA cover faying surface from sealing properly. This allowed hot gas to pass by and the area underneath to be sooted. USBI has prepared an FEC to close out this area with K5NA in a manner similar to the end cover corner locations, which previously experienced similar problems.

The suspect 2 inch bulge in the RH forward field joint at 185 degrees was examined during disassembly. The bulge was a section of cork that had expanded from water absorption and indicates a cork treatment process anomaly. The cork had not debonded from the substrate moisture seal.

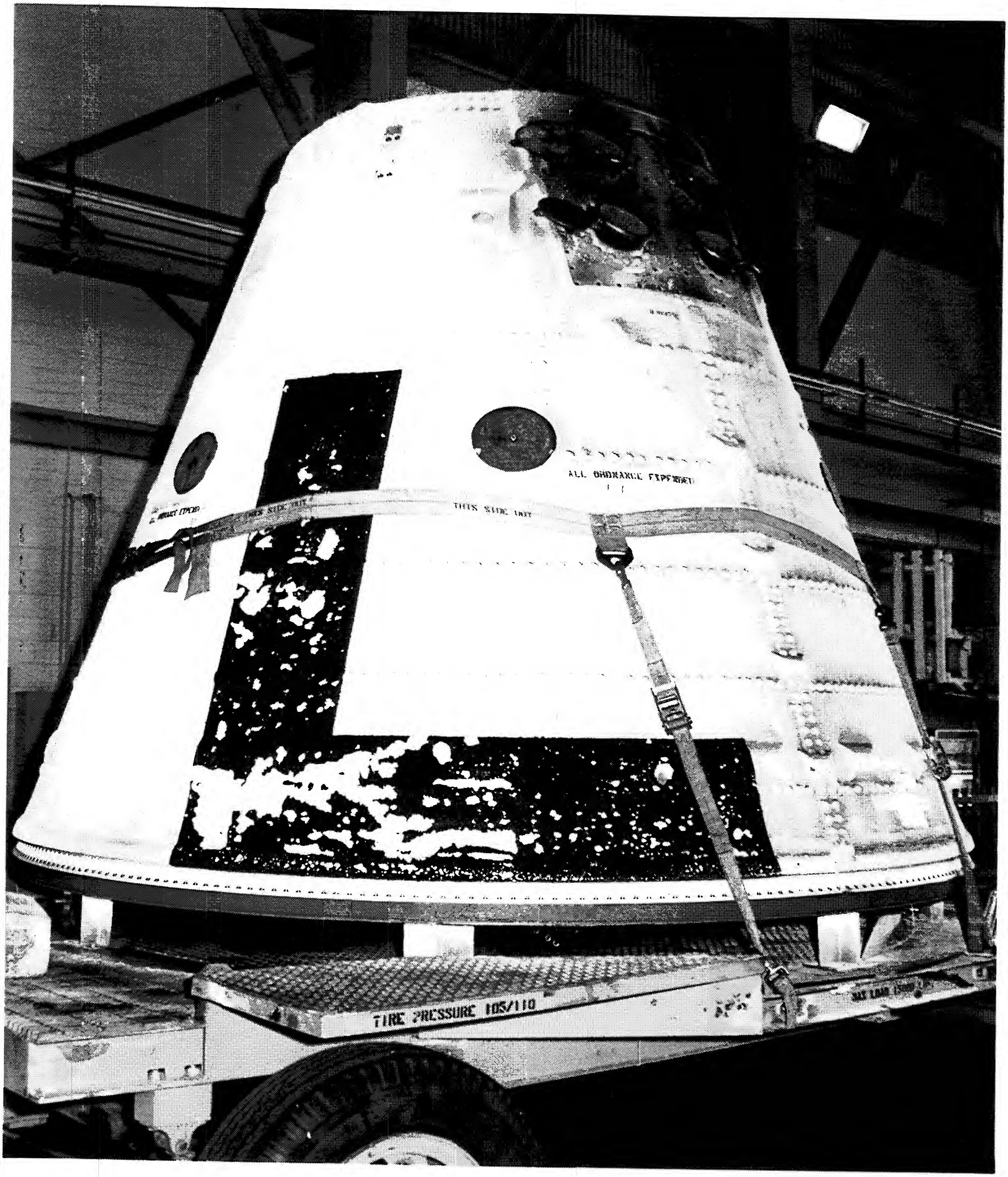
Disassembly of the igniters showed the usual, and according to MTI - expected, blow holes in the putty, but there was no evidence of the putty approaching too close to the gask-o-seal.

A program decision prior to launch had removed the frangible link between the DCS plunger and the holddown stud because of suspected stud hang-up problems. Although there were no stud hang-ups on this flight, this change allowed a considerable amount of frangible nut debris to escape the DCS's. USBI measured the percentage of potential debris retained, but the total does not include the frangible nut halves:

HDP #1	45%	HDP #5	32%
HDP #2	53%	HDP #6	70%
HDP #3	35%	HDP #7	91%
HDP #4	68%	HDP #8	59%

The quantity of debris lost from the DCS on this flight is considered by the Debris Team to be unacceptable and a potential hazard to the vehicle.

Post launch anomalies are listed in Section 11.3.



Overall view of RH frustum. Black Hypalon paint in visibility stripe has blistered and peeled away.

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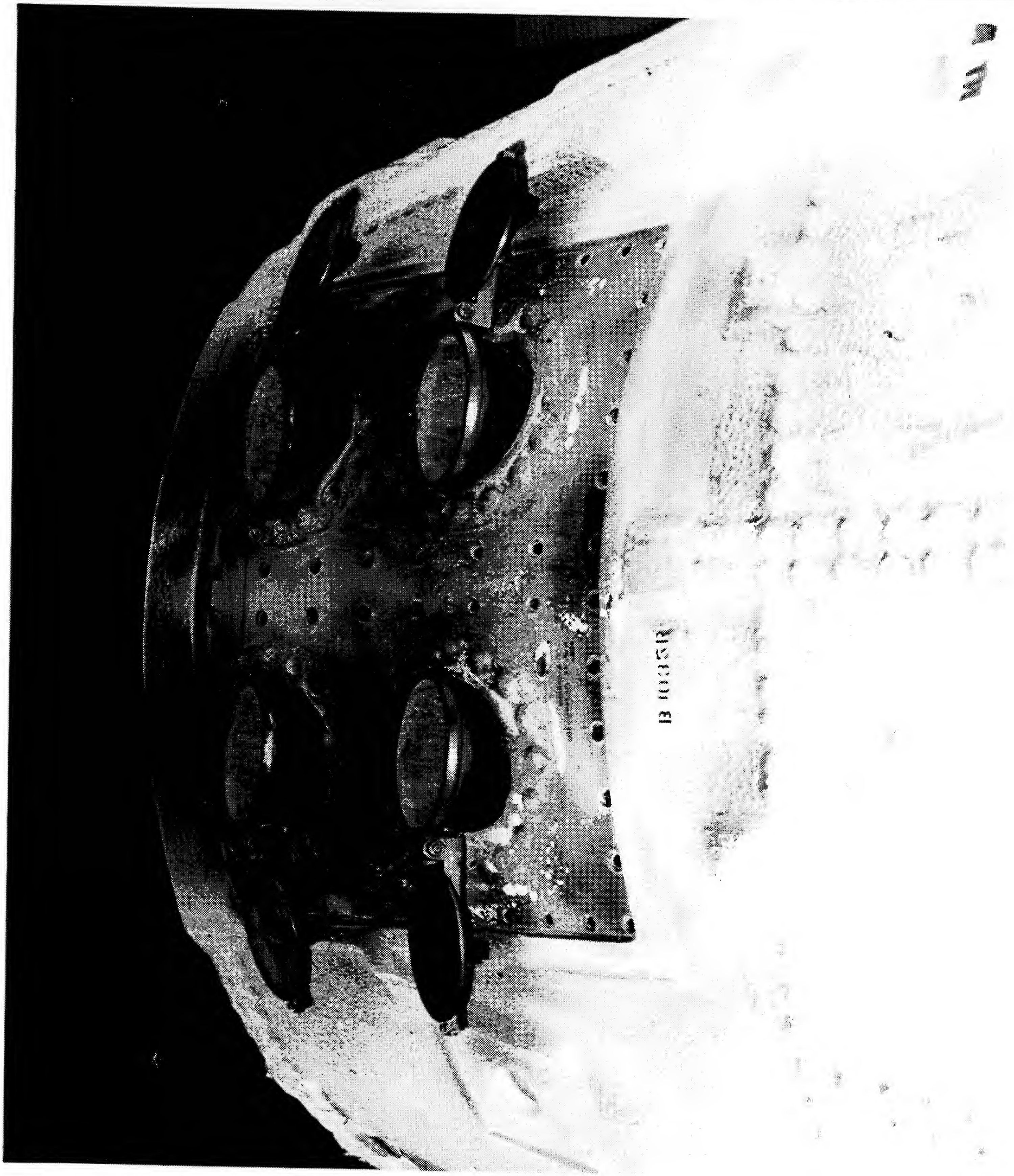
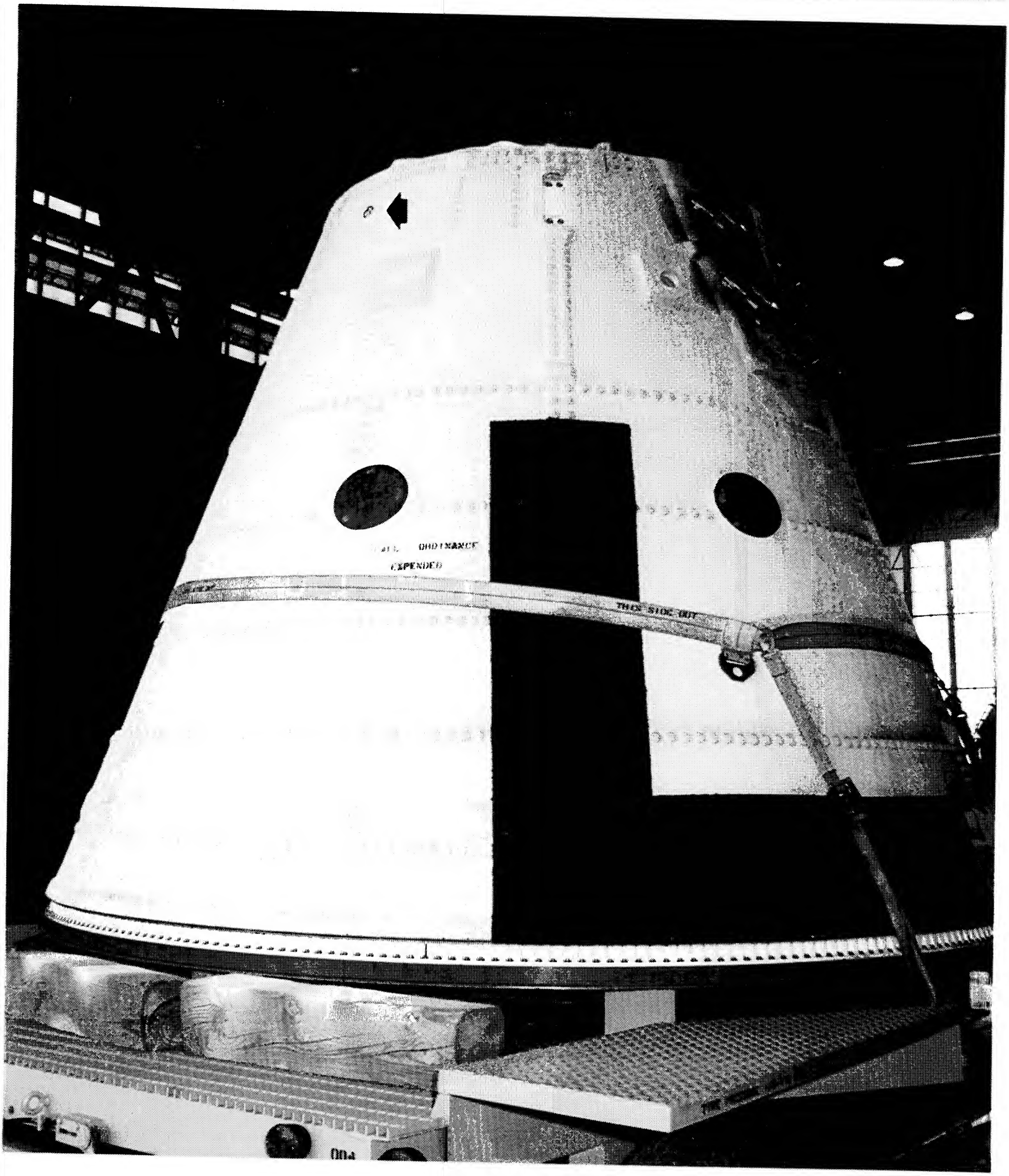
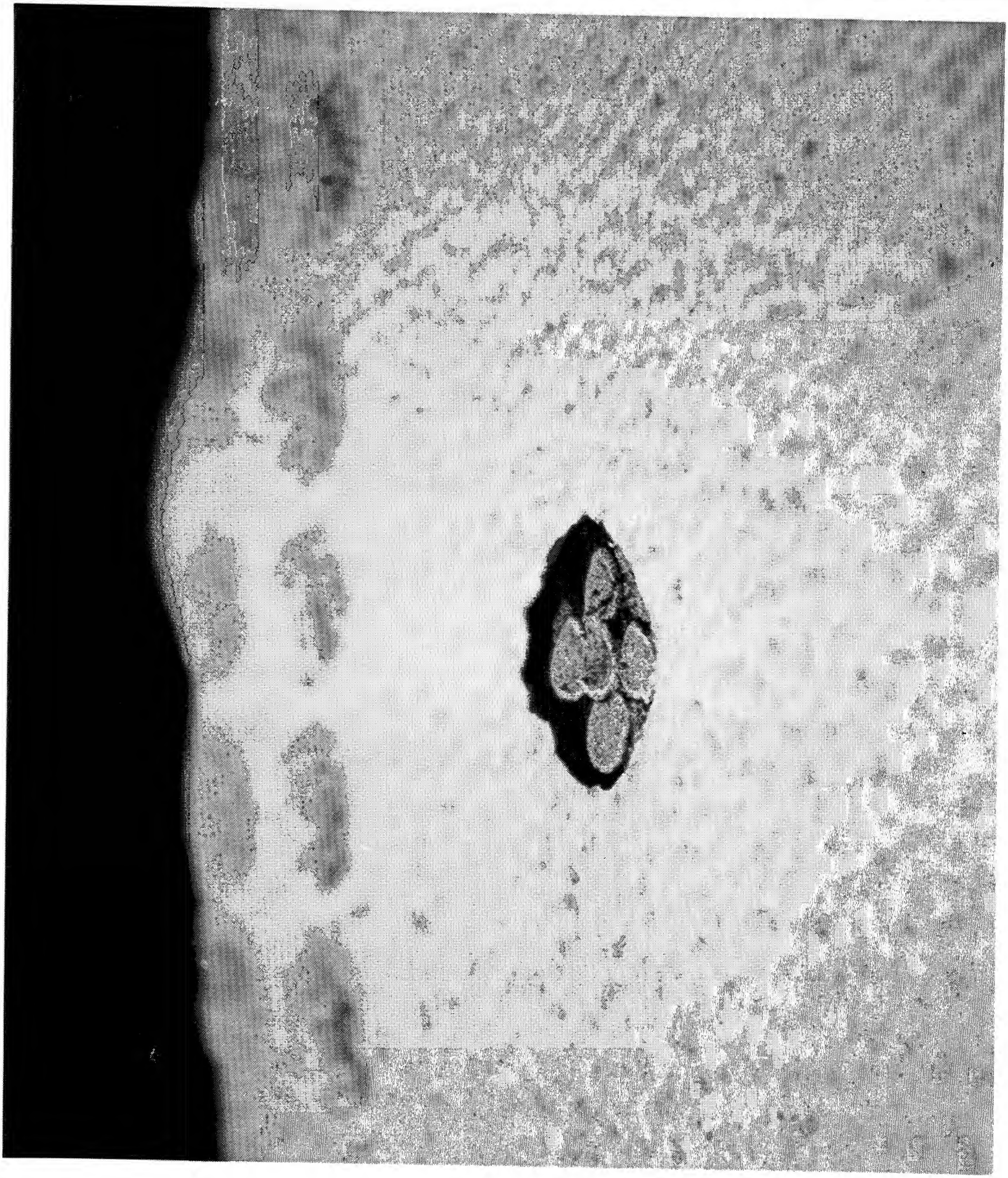


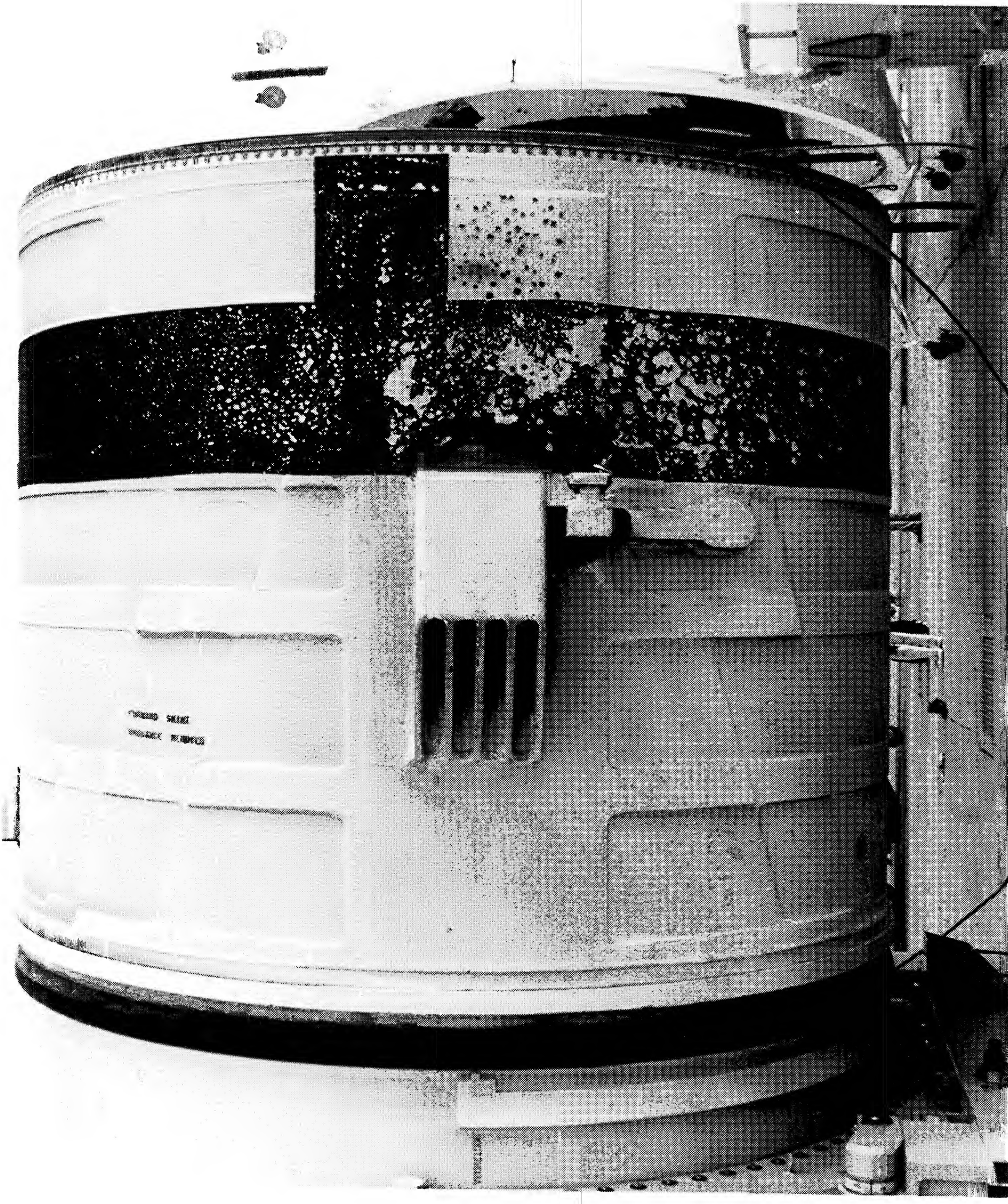
All forward BSM covers were fully opened and properly locked in the 180-degree position



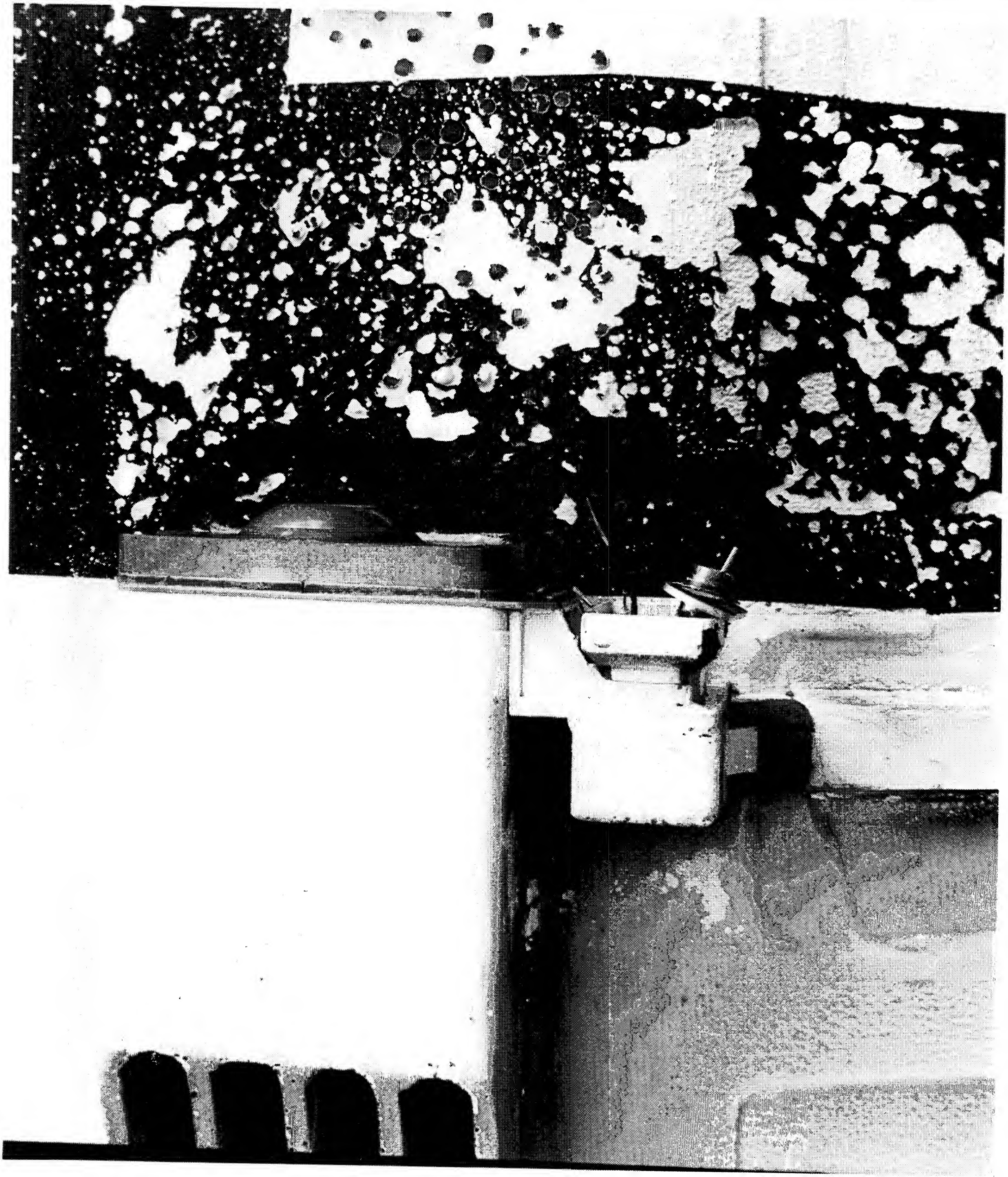
Overall view of LH frustum. A two inch diameter piece of MSA is missing from an area near the 275 ring.



Close-in view of missing MSA near the 275 ring frame



Overall view of LH forward skirt. Some MSA adhered to the Hypalon paint blisters forward of the thrust fitting.



Close-in view of Hypalon paint blisters with MSA attached

LH SRB +Z RSS antenna phenolic plate lost some material from the delaminated layers

Typical condition of SRB cases after flight/retrieval

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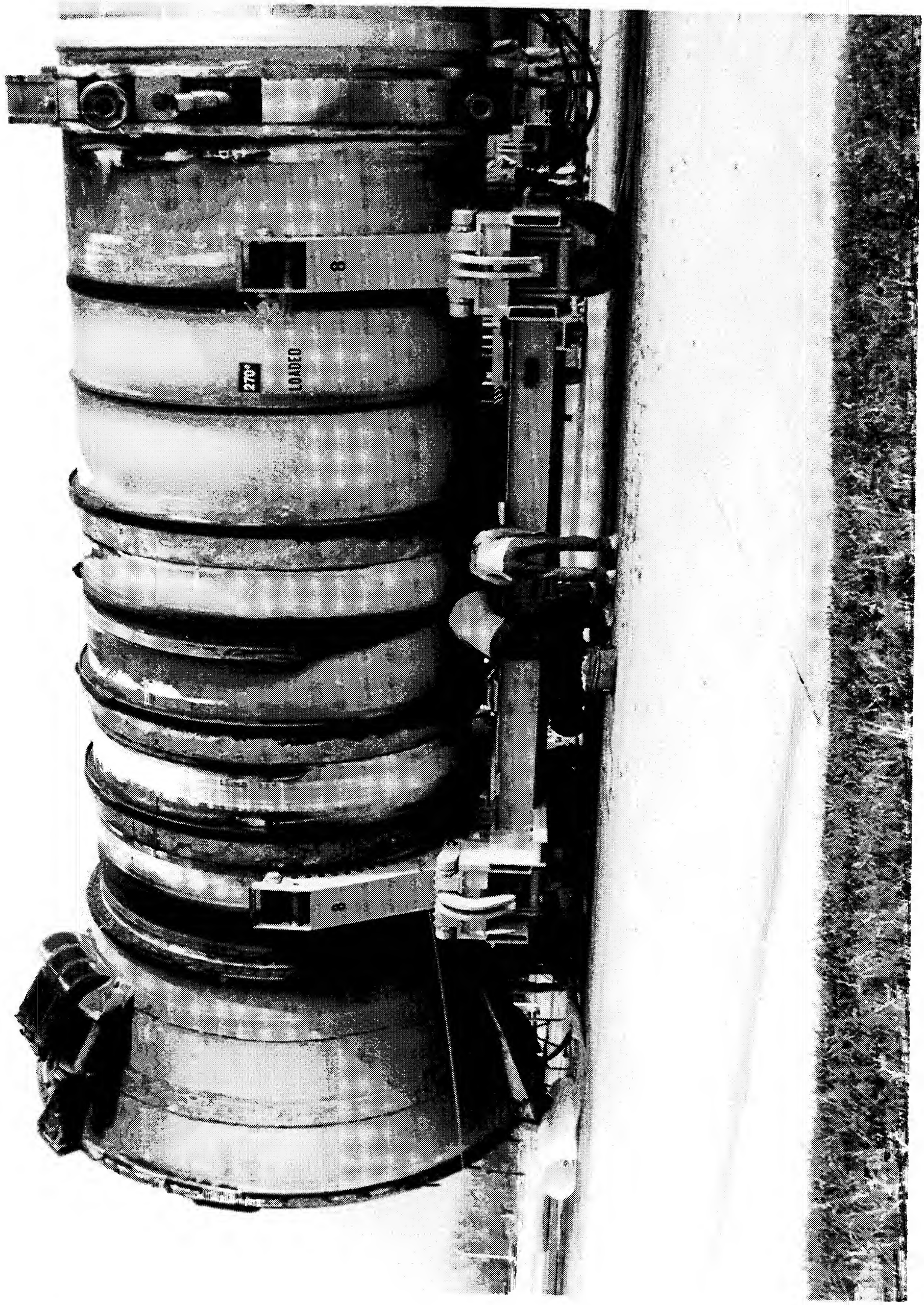
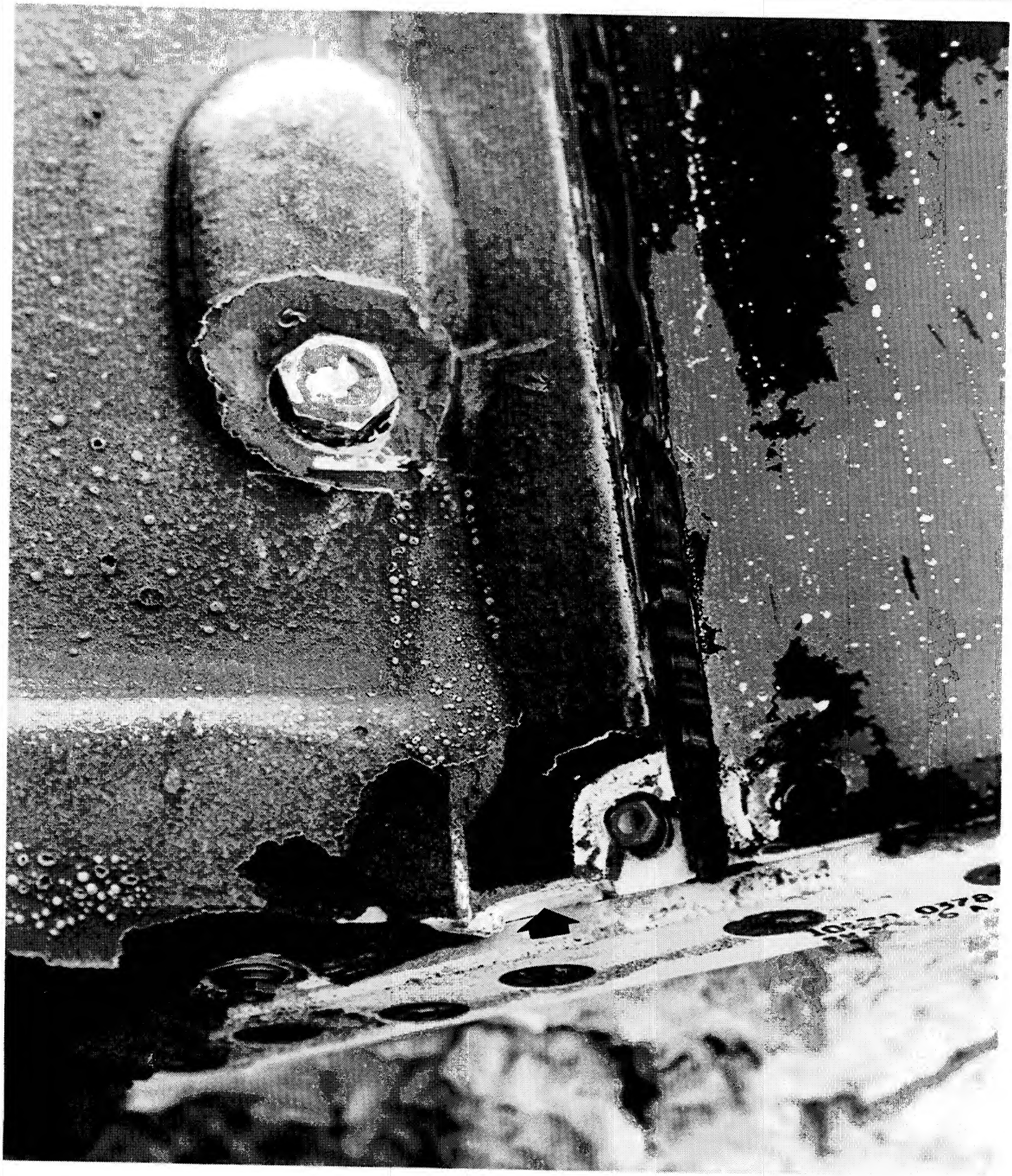
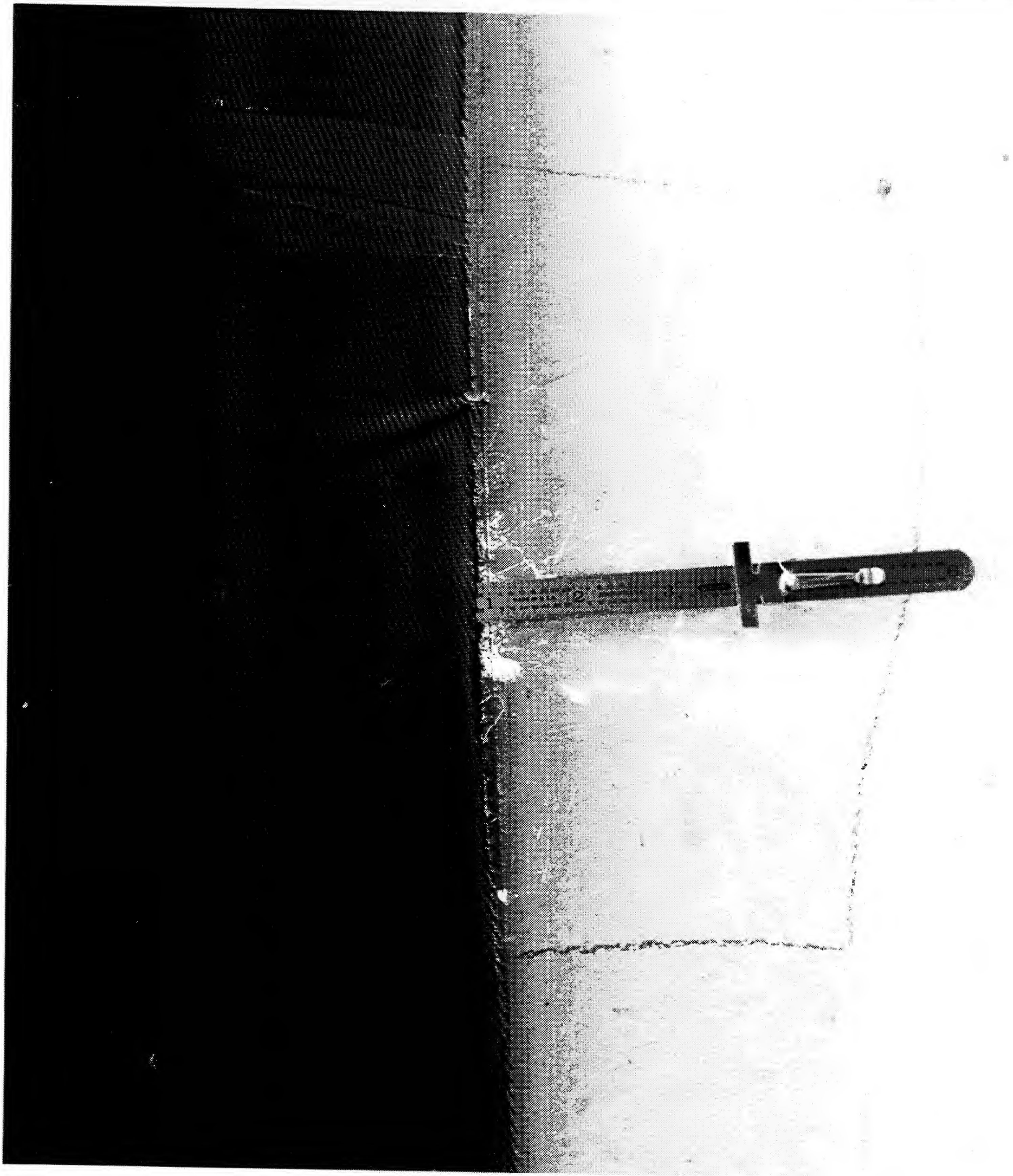


Overall view of aft booster after flight/retrieval

Missing bolt head and torn/missing EPDM cover at RH upper strut



Missing ablator and broken/missing corner to RH ETA cover



Debond on leading edge of LH aft booster factory joint EPDM moisture seal

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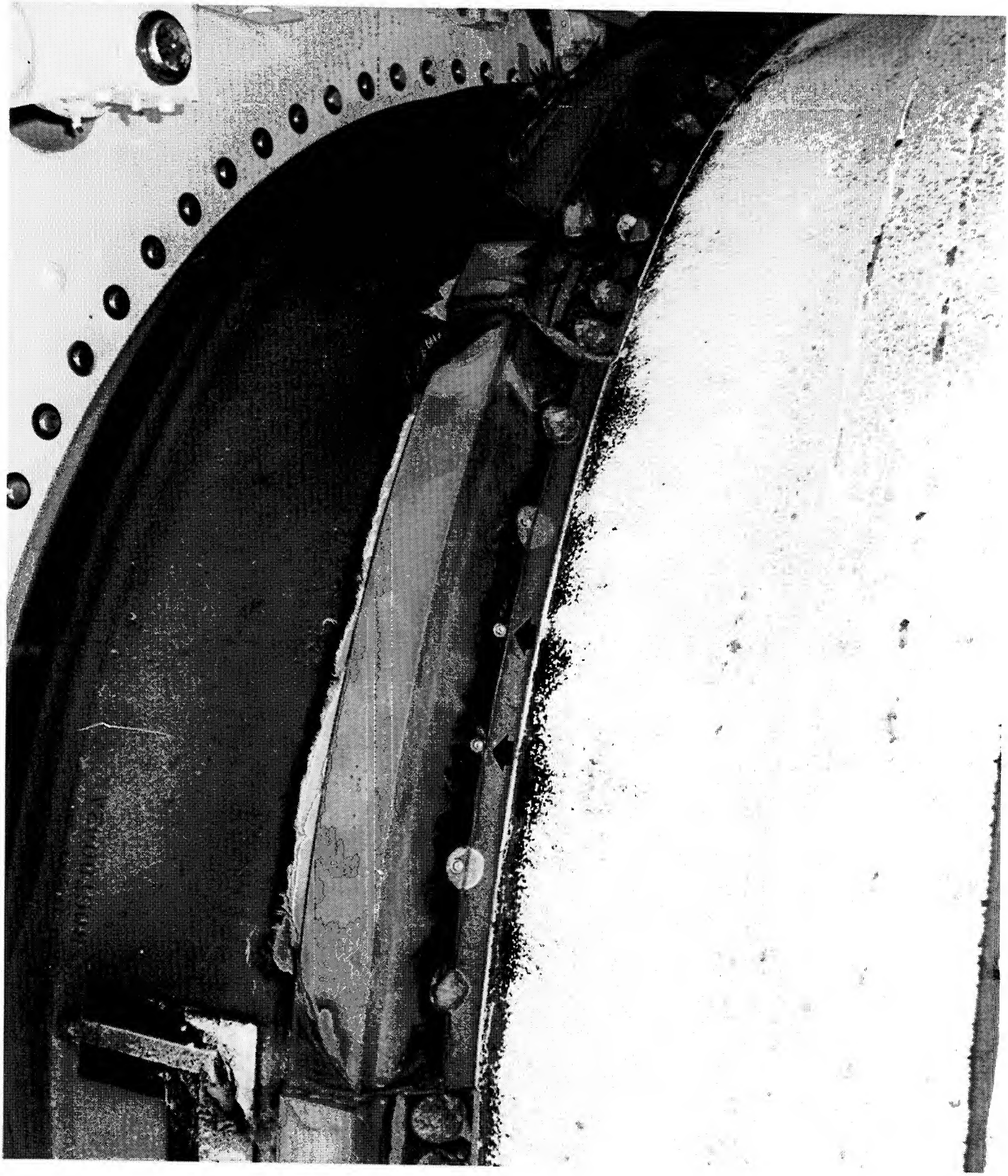
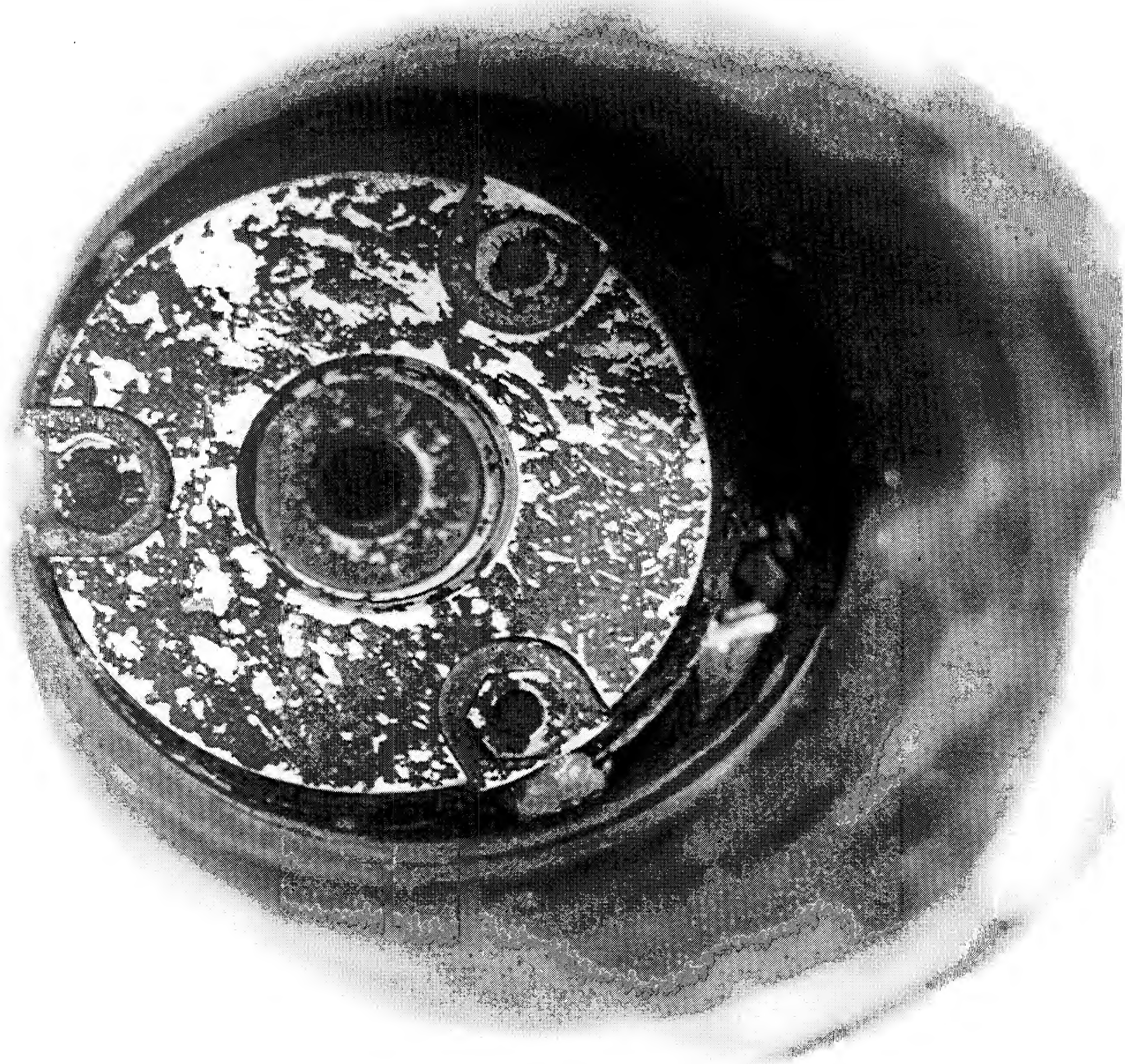
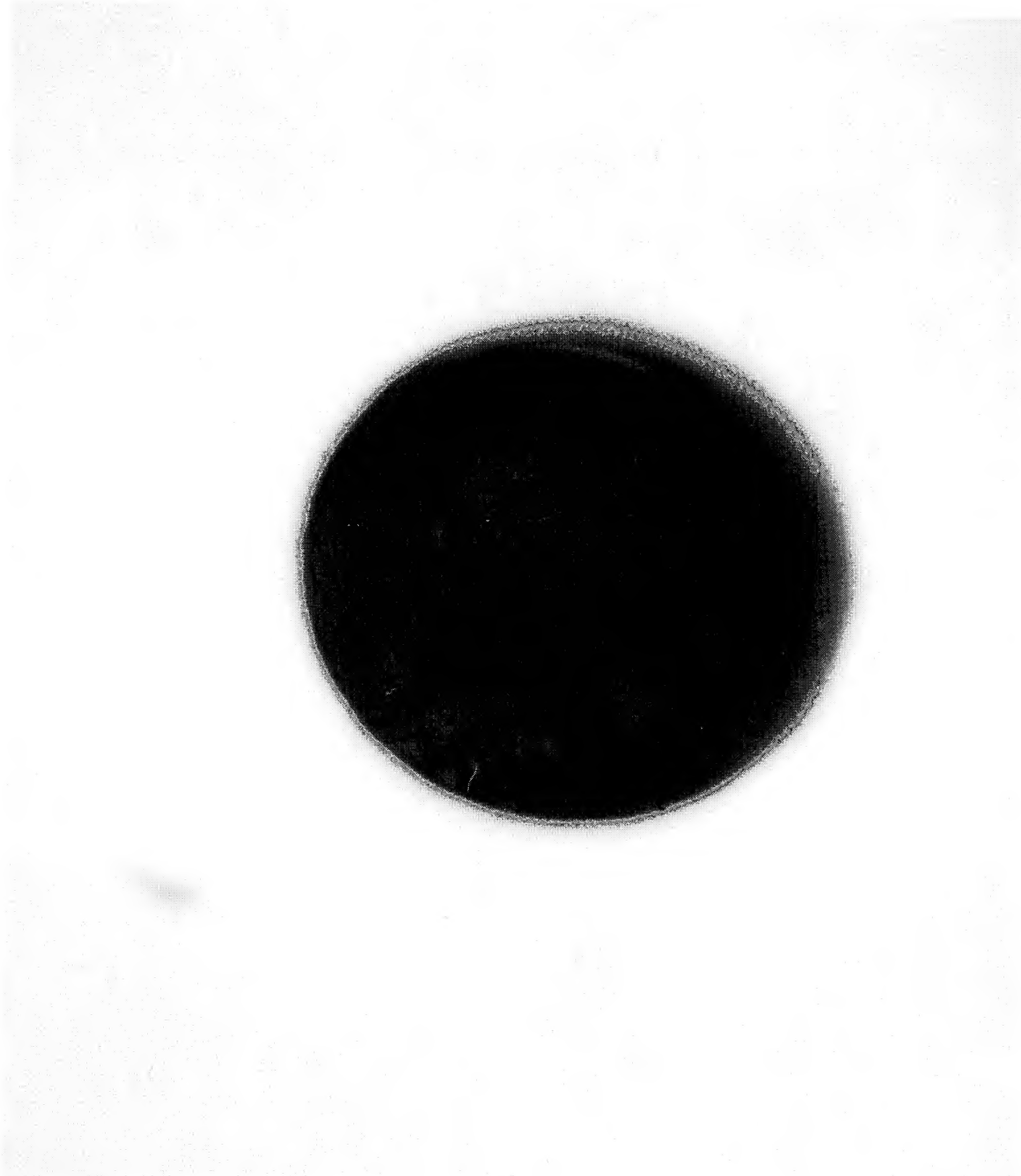


Phenolic delamination on aft kick ring. Note missing bolt head K5NA protective domes (arrows).

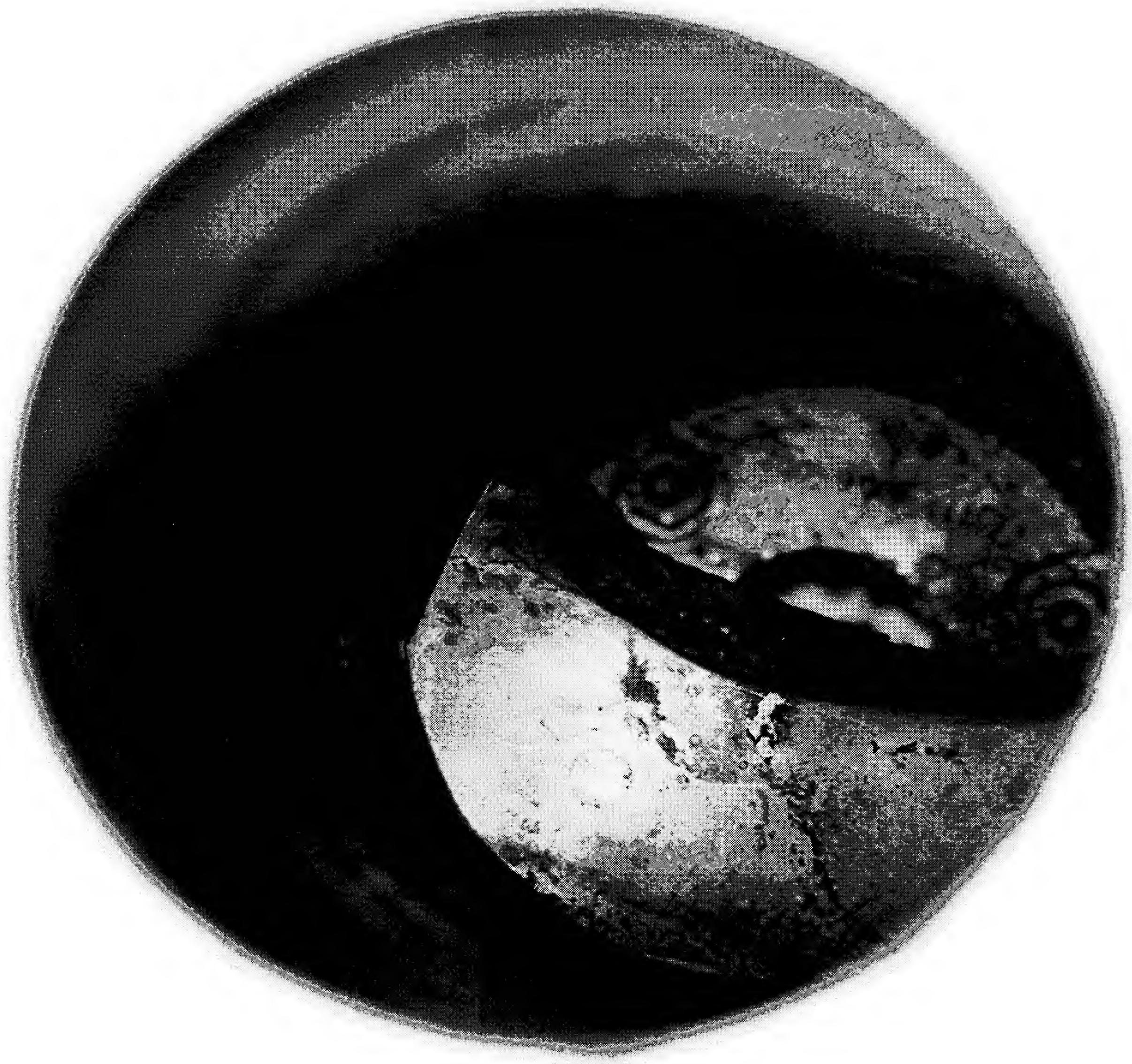
Piece of SRB aft skirt thermal curtain pinched between HDP #8 debris plunger and spherical washer



Small pieces of ordnance debris and shim material are wedged between HDP #7 and spherical washer



Frangible nut pieces have prevented the HDP #3 debris plunger from seating properly



Half of a frangible nut is wedged against the HDP #1 debris plunger in the aft skirt stud hole

9.0 ORBITER POST LANDING DEBRIS ASSESSMENT

A detailed Post Landing Inspection of OV-102 (Columbia) was conducted January 20-21, 1990, at Ames-Dryden (EAFB) on Runway 22 and in the Mate/Demate Device (MDD) to identify debris impact damage, and if possible, debris sources. The Orbiter TPS sustained a total of 120 hits, of which 15 had a major dimension of 1-inch or greater. This total does not include the approximately 100 hits on the base heat shield.

The Orbiter lower surface had a total of 111 hits, of which 13 had a major dimension of 1-inch or greater. A heavy concentration of hits (50) occurred just aft and inboard of the LH2 umbilical. This concentration of hits has occurred previously and is attributed to umbilical ice impacts during ET separation. The remainder of the lower surface damage was approximately divided equally about the vehicle centerline. A comparison of these numbers to statistics from 19 previous missions of similar configuration (excluding missions STS-24, 25, 26, 26R, 27R, and 30, which had damage from known debris sources), indicates the total number of hits on the lower surface is average. Also, based on the severity of damage as indicated by surface area and depth, this flight is considered to be better than average. Figures 20-23 show the TPS debris damage assessment for STS-32R.

The single, largest, lower surface damage site occurred on the RH chine and measured 2" x 3" x 1/2".

Damage to the base heat shield tiles was average. The main engine closeout blankets were only slightly damaged. The blankets sustained damage at the 6 o'clock position on SSME #1, the 2-4 o'clock position on SSME #2, and the 7 o'clock position on SSME #3. No damage to the SSME nozzle insulation was visible.

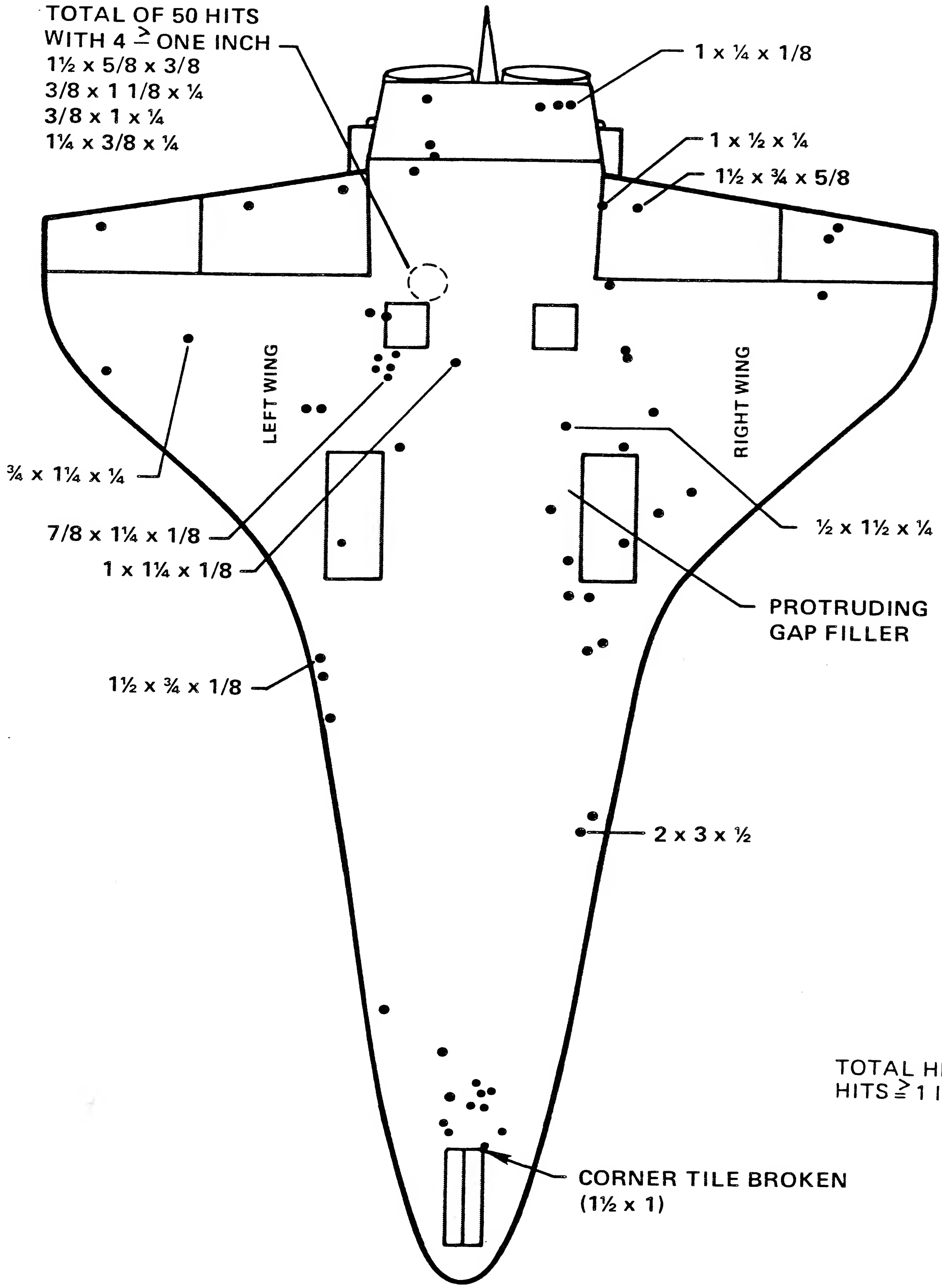
Several pieces of gap filler sleeving material were loose on both RH and LH OMS pods leading edges and near the LO2 T-0 umbilical. No detectable damage to adjacent tiles resulted from these gap fillers.

Six typical white streaks were present on the RH wing leading edge RCC panels. Orbiter window #3 was heavily hazed, window #4 was lightly hazed, and window #2 had two streaks.

Samples of deposits/material were taken from windows #1-8, the streaked RCC wing panels, and other selected damage sites as shown in Figures 24-25 for laboratory analysis.

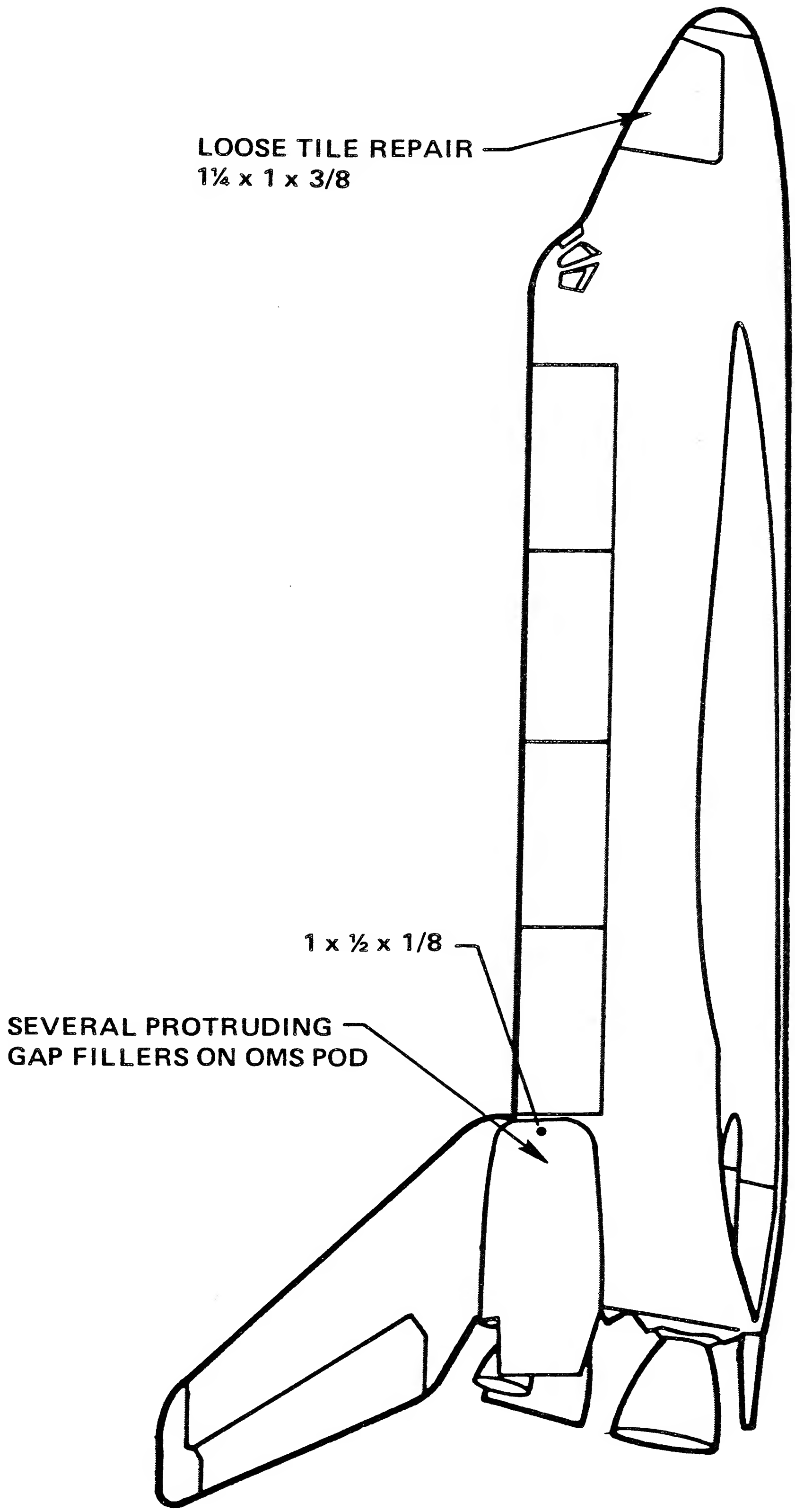
The separation ordnance devices appeared to function properly. The plungers seated on EO-2 and EO-3, and the EO-1 bipod yoke bolt piston was flush with the outer mold line. Closer inspection of EO-1 revealed the ordnance device had rotated forward sufficiently to contact both RH and LH bulkhead pyro connector

FIGURE 20. **DEBRIS DAMAGE LOCATIONS**



EGG/V-088B

FIGURE 21. **DEBRIS DAMAGE LOCATIONS**



TOTAL HITS = 1
HITS ≥ 1 INCH = 1

EGG/V–088A

FIGURE 22. **DEBRIS DAMAGE LOCATIONS**

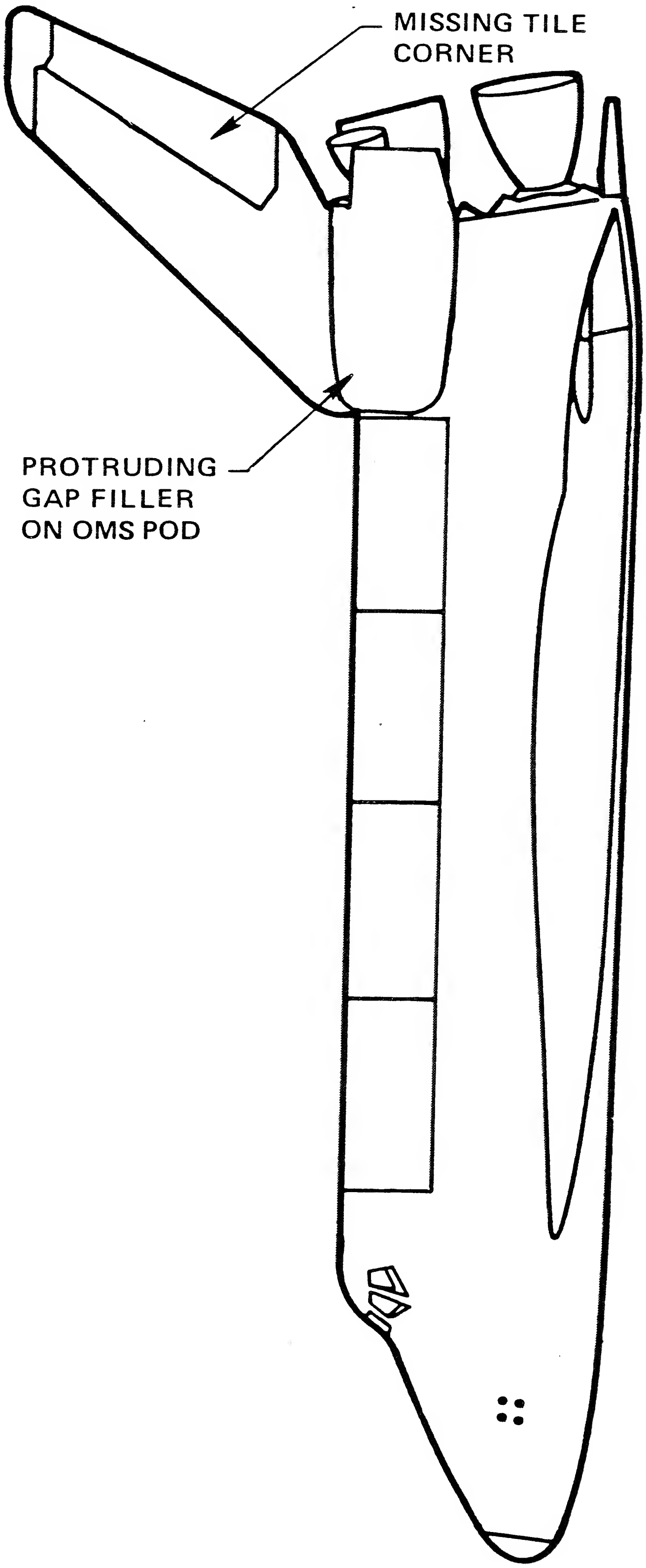
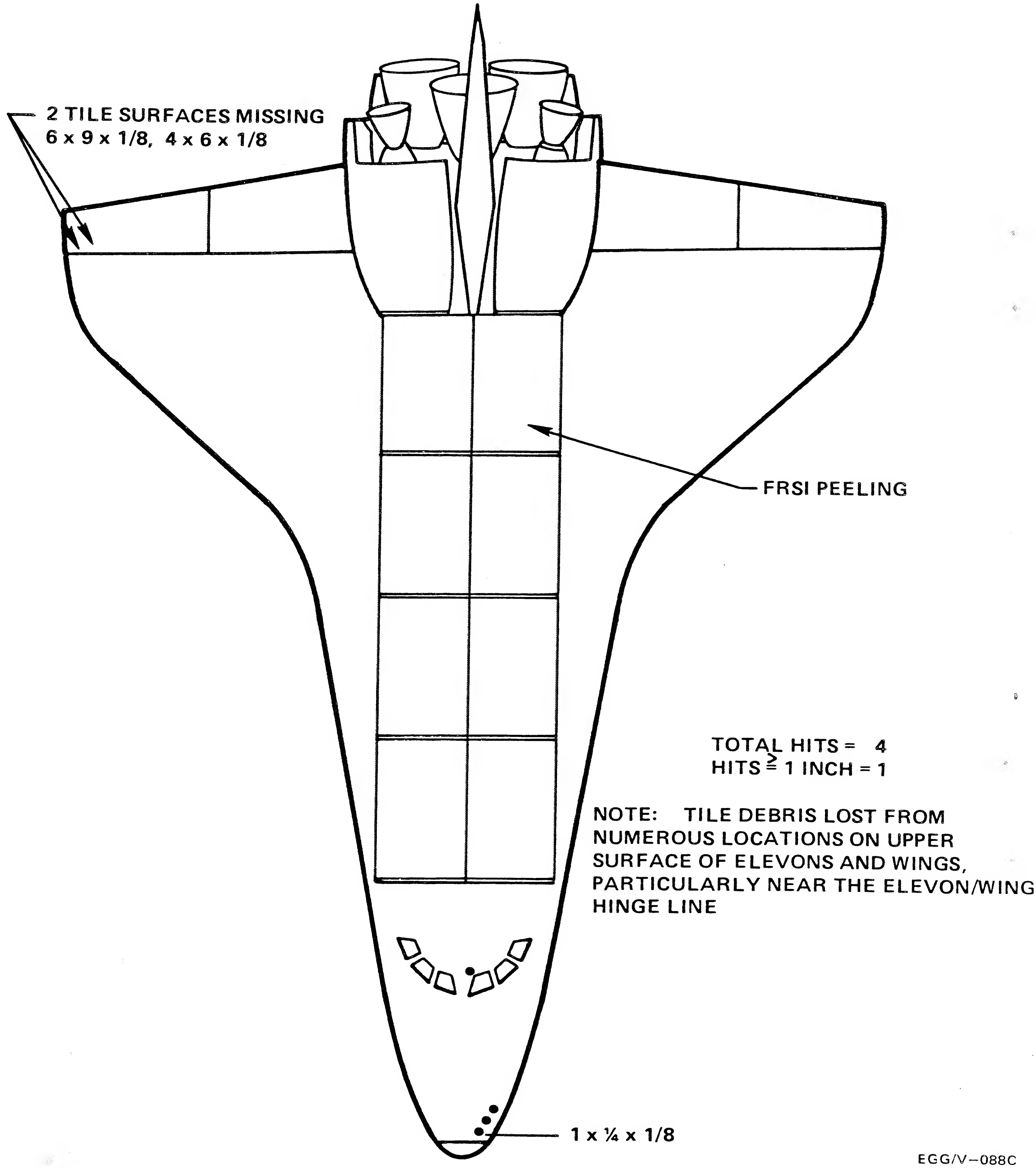


FIGURE 23. DEBRIS DAMAGE LOCATIONS



EGG/V−088C

FIGURE 24. **STS-32R DEBRIS DAMAGE CHEMICAL SAMPLE LOCATIONS**

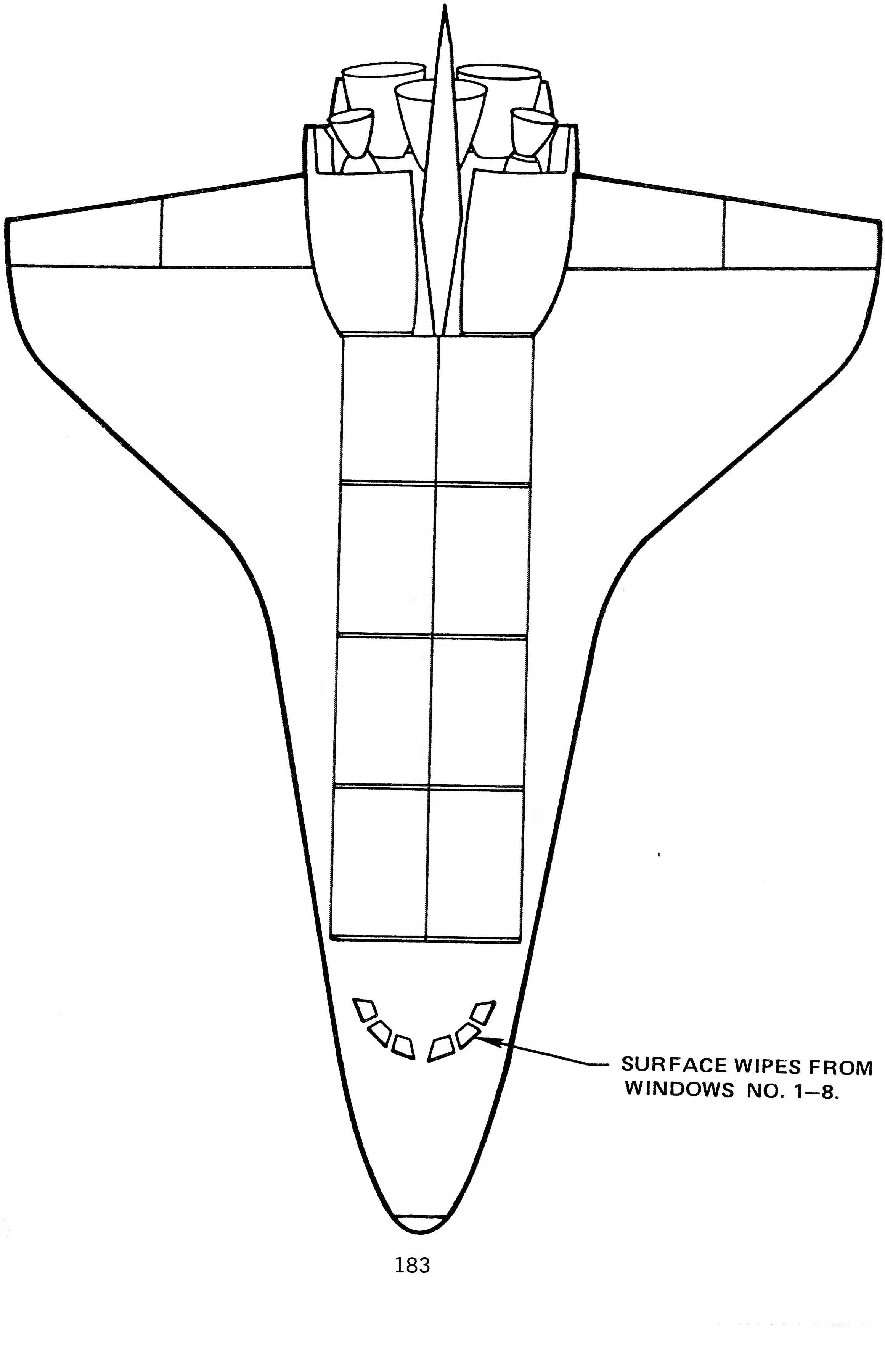


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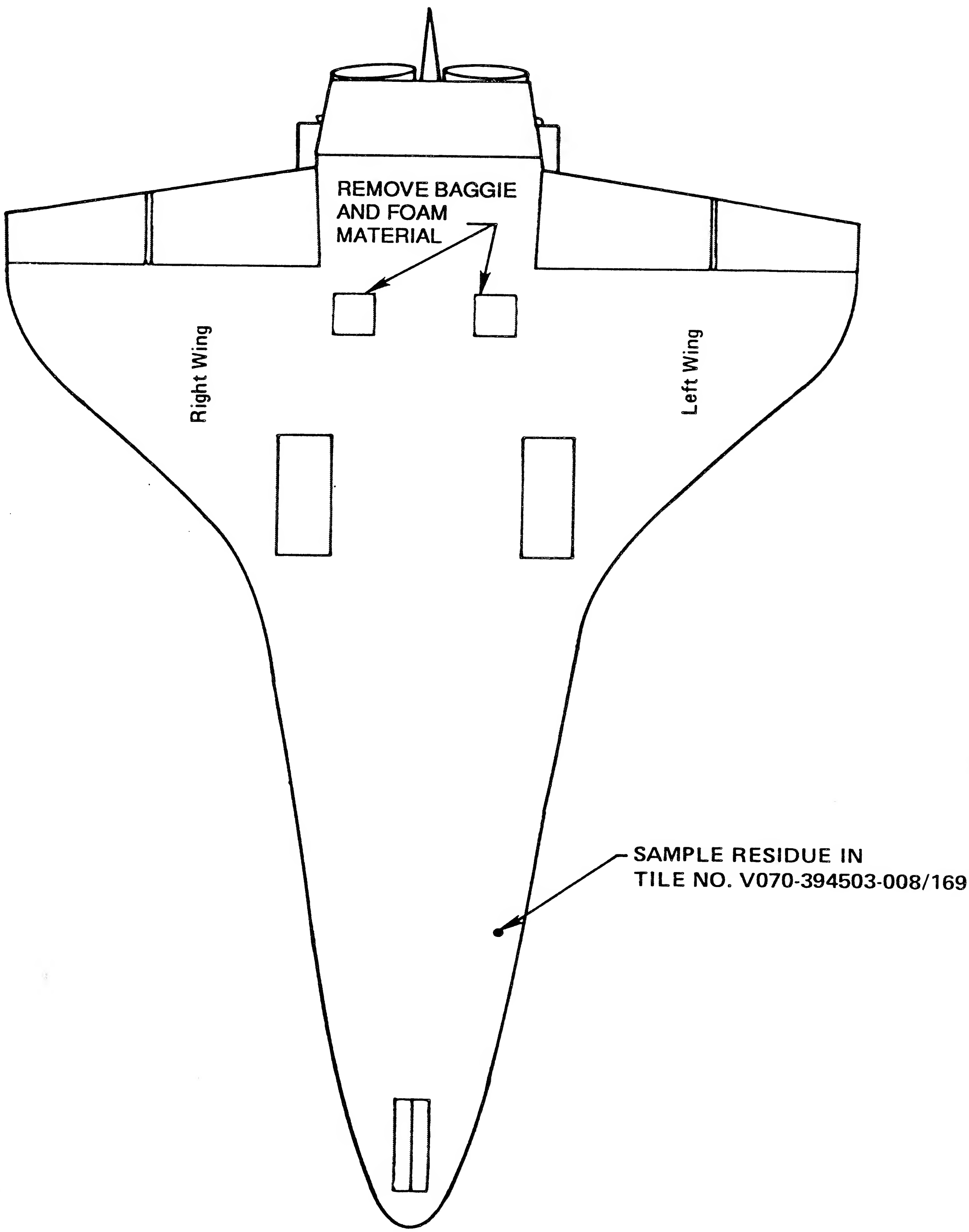
FIGURE 25. **STS-32R DEBRIS DAMAGE CHEMICAL SAMPLE LOCATIONS**



backshells, as evidenced by scratch marks on the ordnance device spring housings. The backshells were not broken as in STS-33R. The RH Y-Y centering bolt, which had bent on STS-34, showed signs of compressive loading.

No TPS damage was attributed to material from the tires, wheels, or brakes.

The KSC Shuttle Thermal Imager (STI) was used to record the surface temperatures of several areas on the Orbiter. Twenty-five minutes after landing with an ambient temperature of 33 degrees, the nosecap RCC measured 150 degrees F, the RH wing RCC panel #9 measured 72 degrees F, and the RH wing RCC panel #17 measured 65 degrees F (Figure 26).

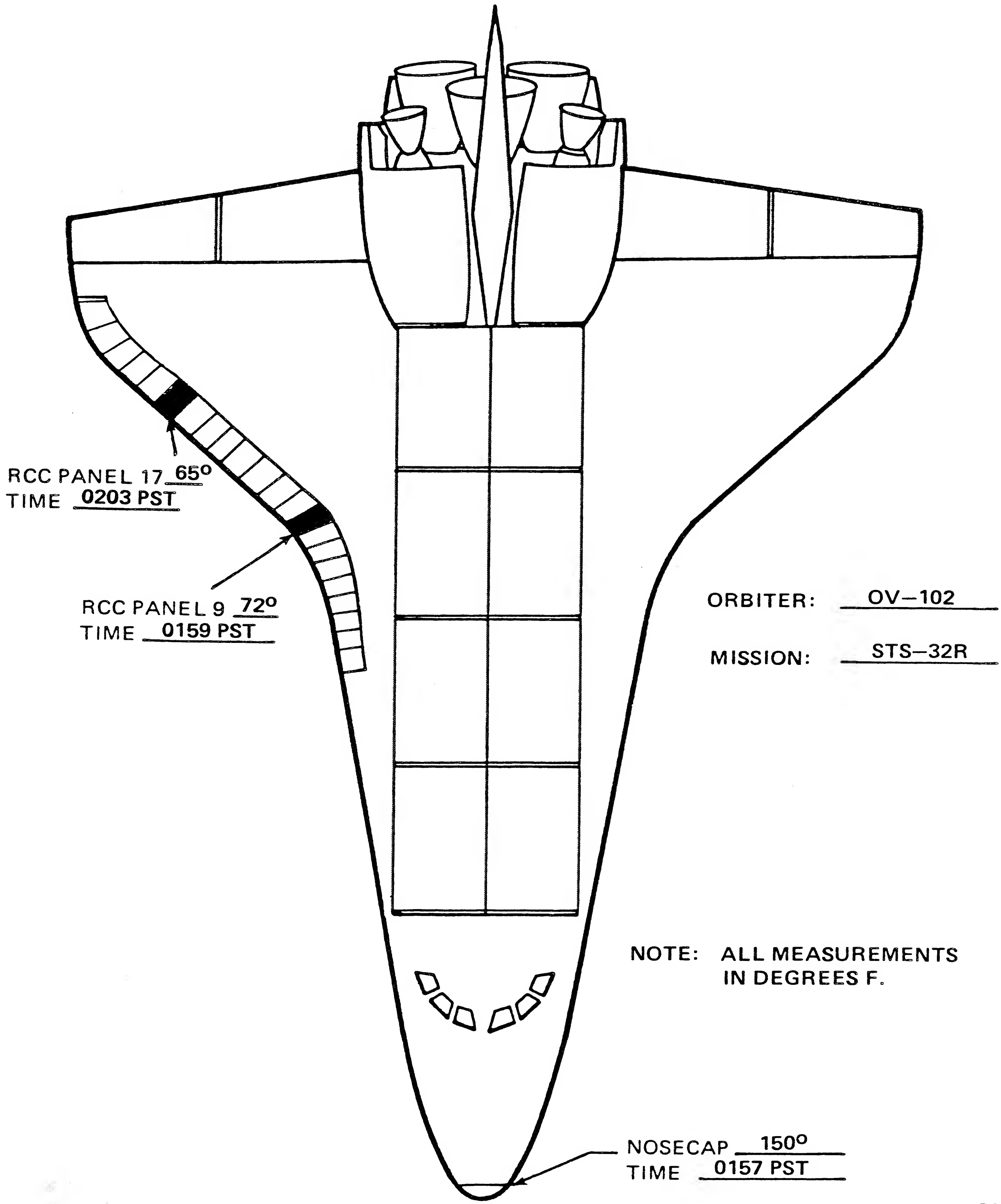
Runways 22 was inspected and cleaned by Air Force personnel on January 18 and 19, 1990. The general condition of the runway was good. The lake bed runways were not inspected because standing water made them unacceptable for landing.

The post landing walkdown of Runway 22 was performed approximately 30 minutes after landing. No flight hardware was found.

In summary, the total number of lower surface Orbiter TPS debris hits was average when compared to previous flights as shown in the comparison charts (Figure 27-28). The distribution of hits on the Orbiter does not point to a single source for ascent debris, but indicates a shedding of ice and TPS debris from random sources. The potential identification of debris sources for mission STS-32R will be based on the laboratory analysis of TPS damage sites, inspection of the recovered SRB components, and photographic analysis.

Orbiter Post Landing Anomalies are listed in Section 11.4.

FIGURE 26. TEMPERATURE MEASUREMENTS



EGG/V–0881

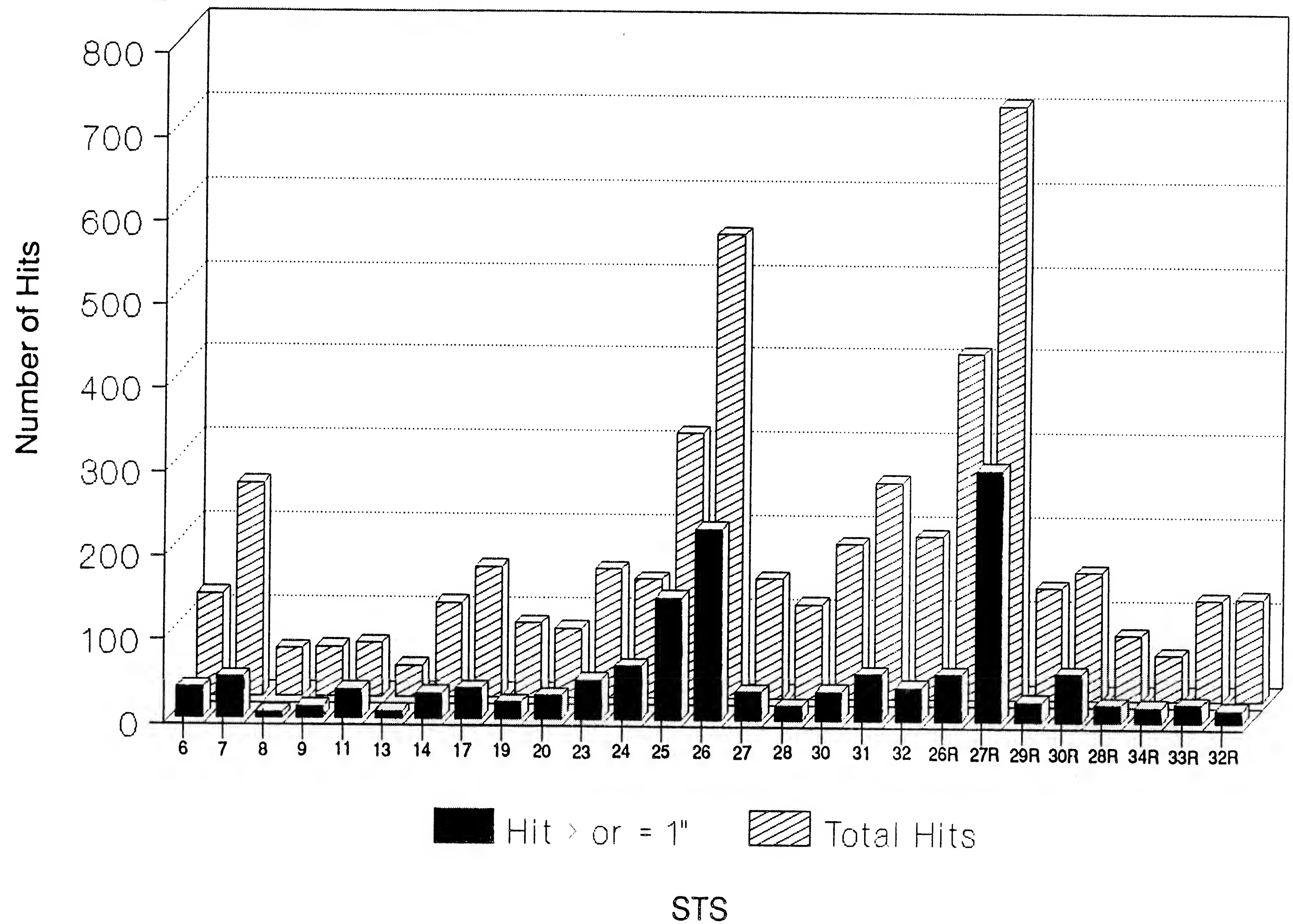
FIGURE 27. STS-32R DEBRIS DAMAGE ASSESSMENT SUMMARY

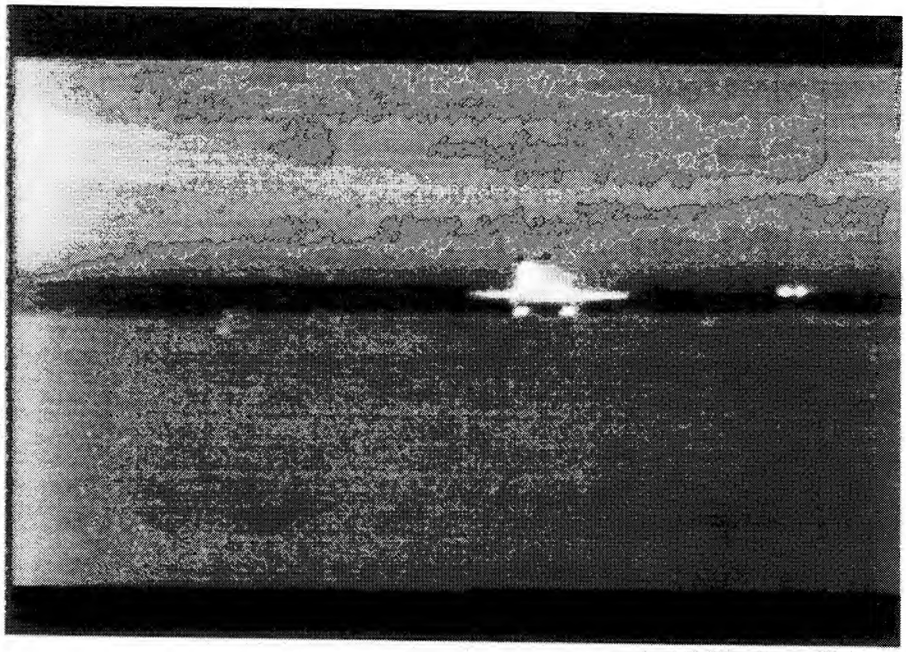
	Hits > or = 1"	Total Hits
Lower Surface	13	111
Upper Surface	1	4
Right Side	0	0
Left Side	0	4
Right OMS Pod	1	1
Left OMS Pod	0	0
TOTALS	15	120

COMPARISON TABLE

STS-6	36	120
STS-7	48	253
STS-8	7	56
STS-9 (41-A)	14	58
STS-11 (41-B)	34	63
STS-13 (41-C)	8	36
STS-14 (41-D)	30	111
STS-17 (41-G)	36	154
STS-19 (51-A)	20	87
STS-20 (51-C)	28	81
STS-23 (51-D)	46	152
STS-24 (51-B)	63	140
STS-25 (51-G)	144	315
STS-26 (51-F)	226	553
STS-27 (51-I)	33	141
STS-28 (51-J)	17	111
STS-30 (61-A)	34	183
STS-31 (61-B)	55	257
STS-32 (61-C)	39	193
STS-26R	55	411
STS-27R	298	707
STS-29R	23	132
STS-30R	56	151
STS-28R	20	76
STS-34	18	53
STS-33R	21	118
STS-32R	15	120

FIGURE 28. COMPARISON TABLE





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Shuttle Thermal Imager infrared views of Orbiter touchdown and rollout. Note tires, RCC nosecap, and APU exhaust near tail.

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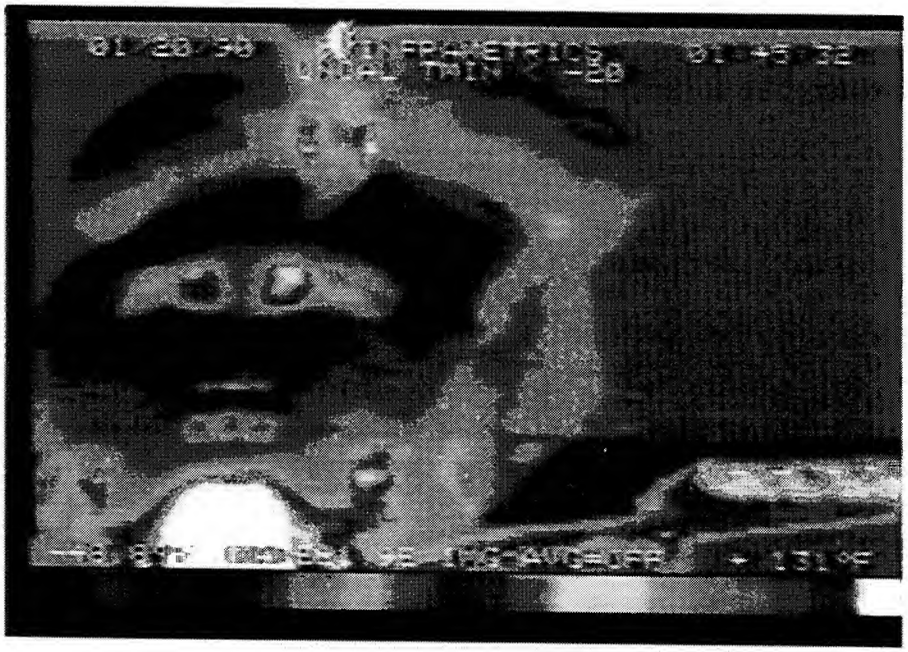

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Colorized STI thermal images show warm areas on RCC nosecap, wing leading edge, and APU exhaust ports near base of tail.

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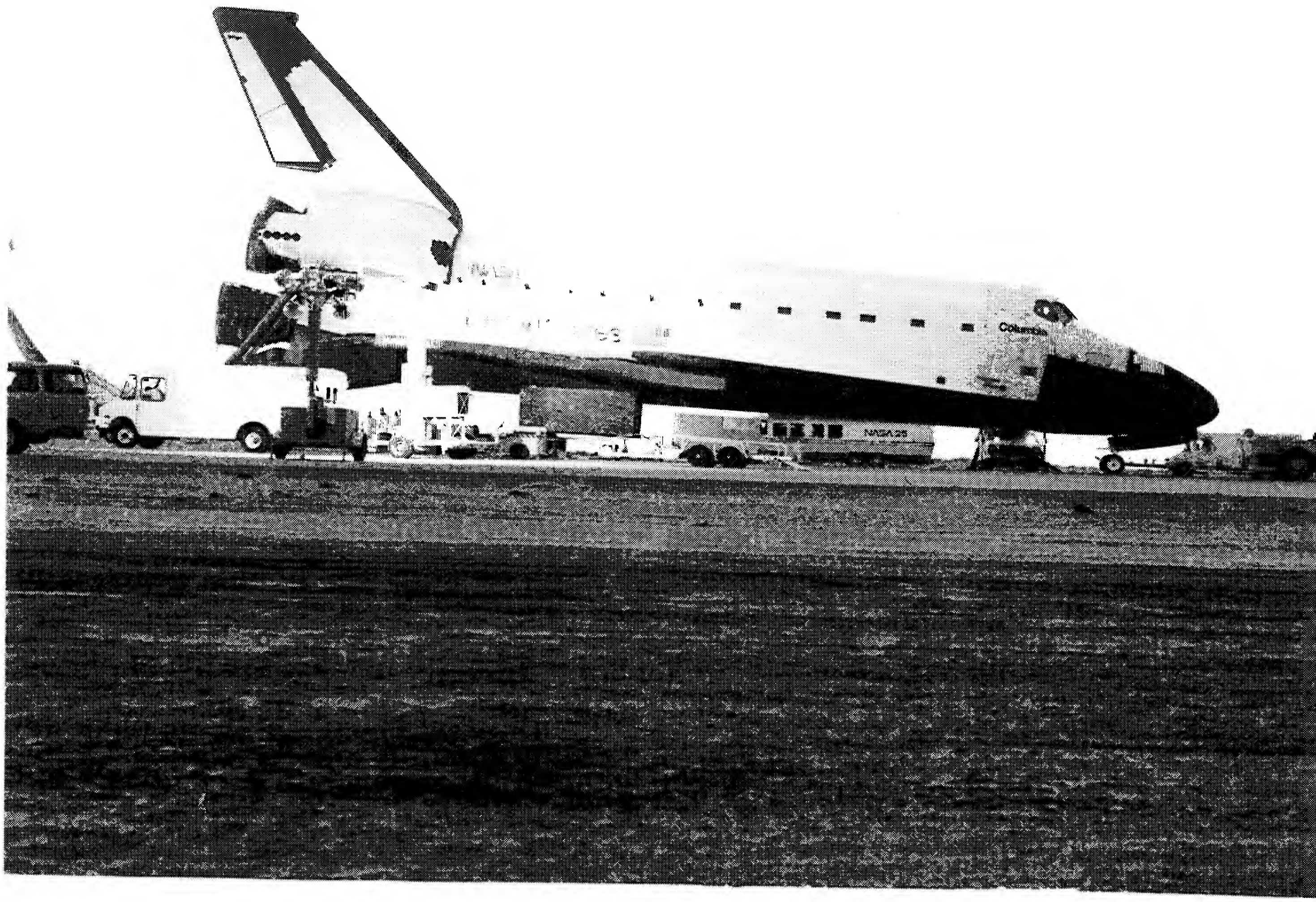
Overall view of Orbiter left side after landing



Overall view of Orbiter right side after landing

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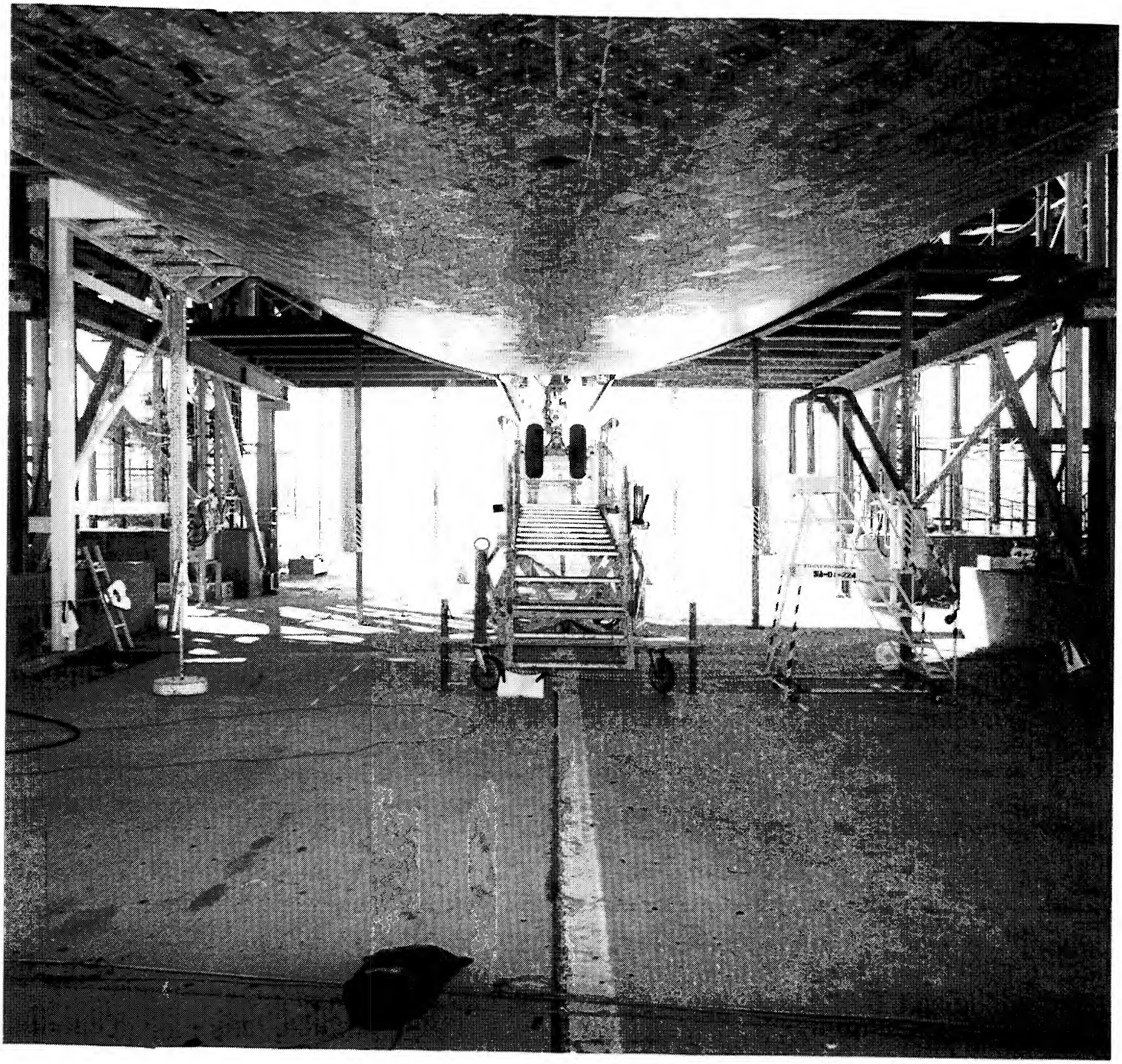
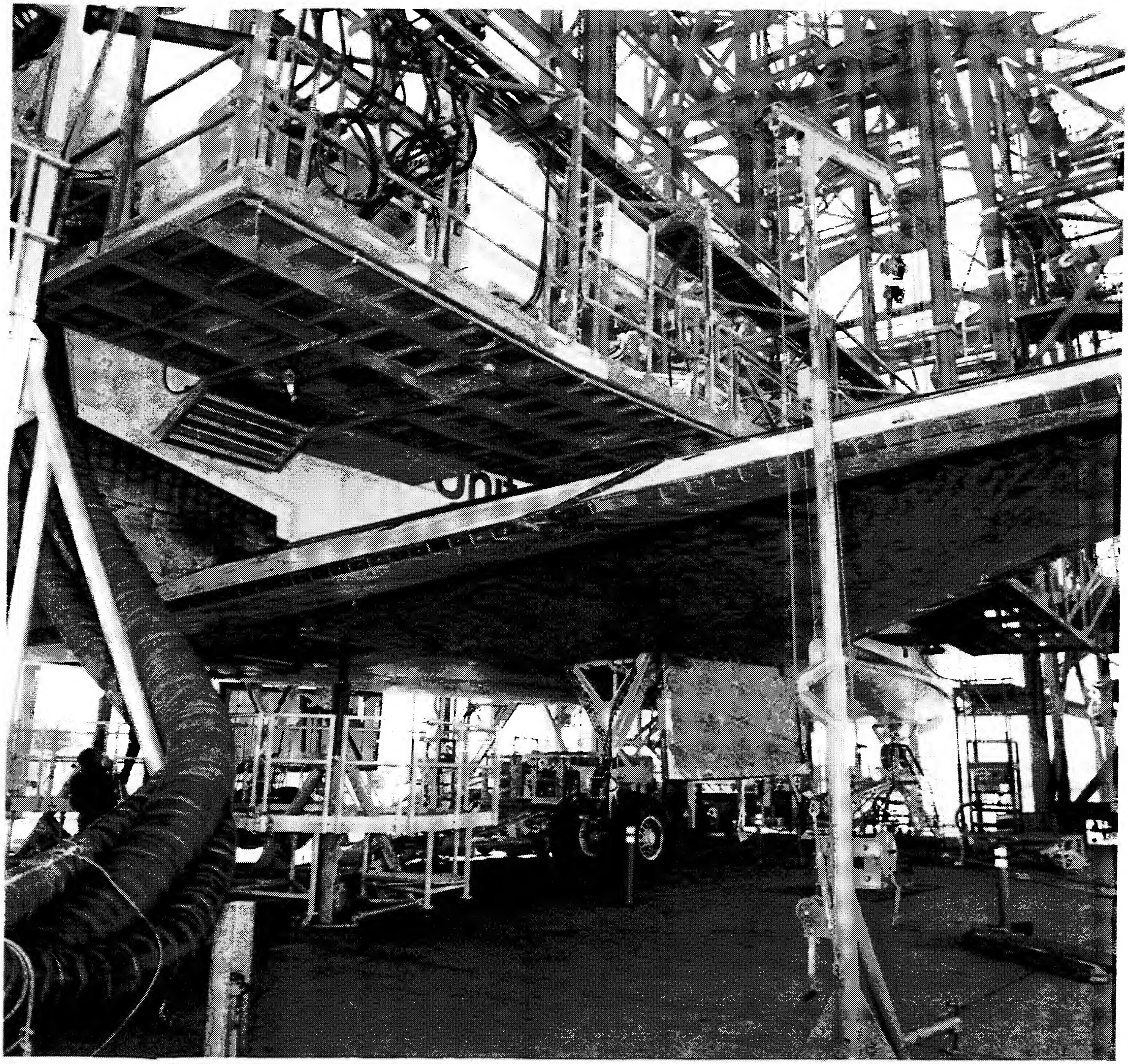
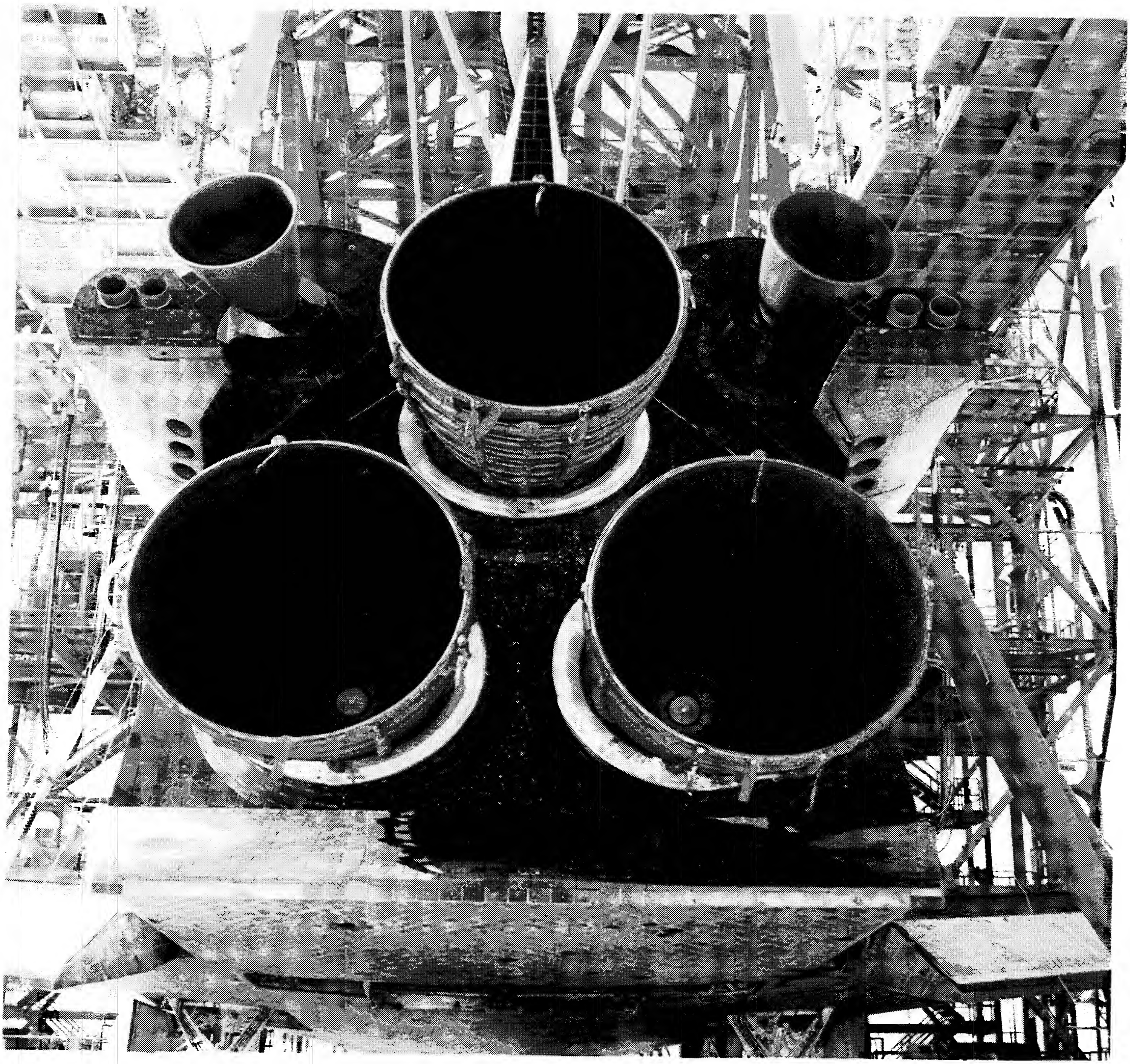


Overall view of lower surface tiles from nose to mid-fuselage

Overall view of lower surface tiles near right chine area

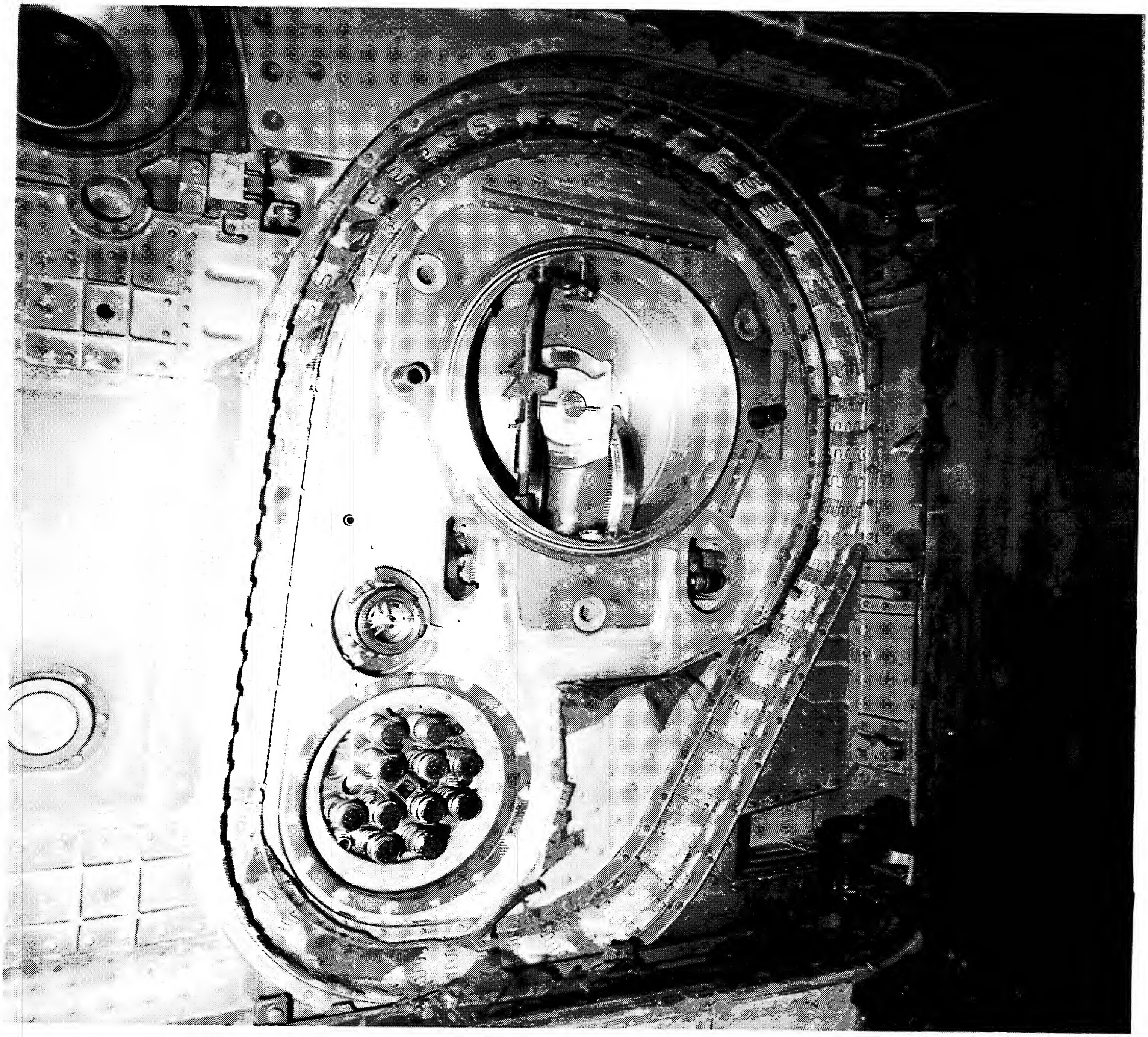


Overall view of right wing lower surface tiles

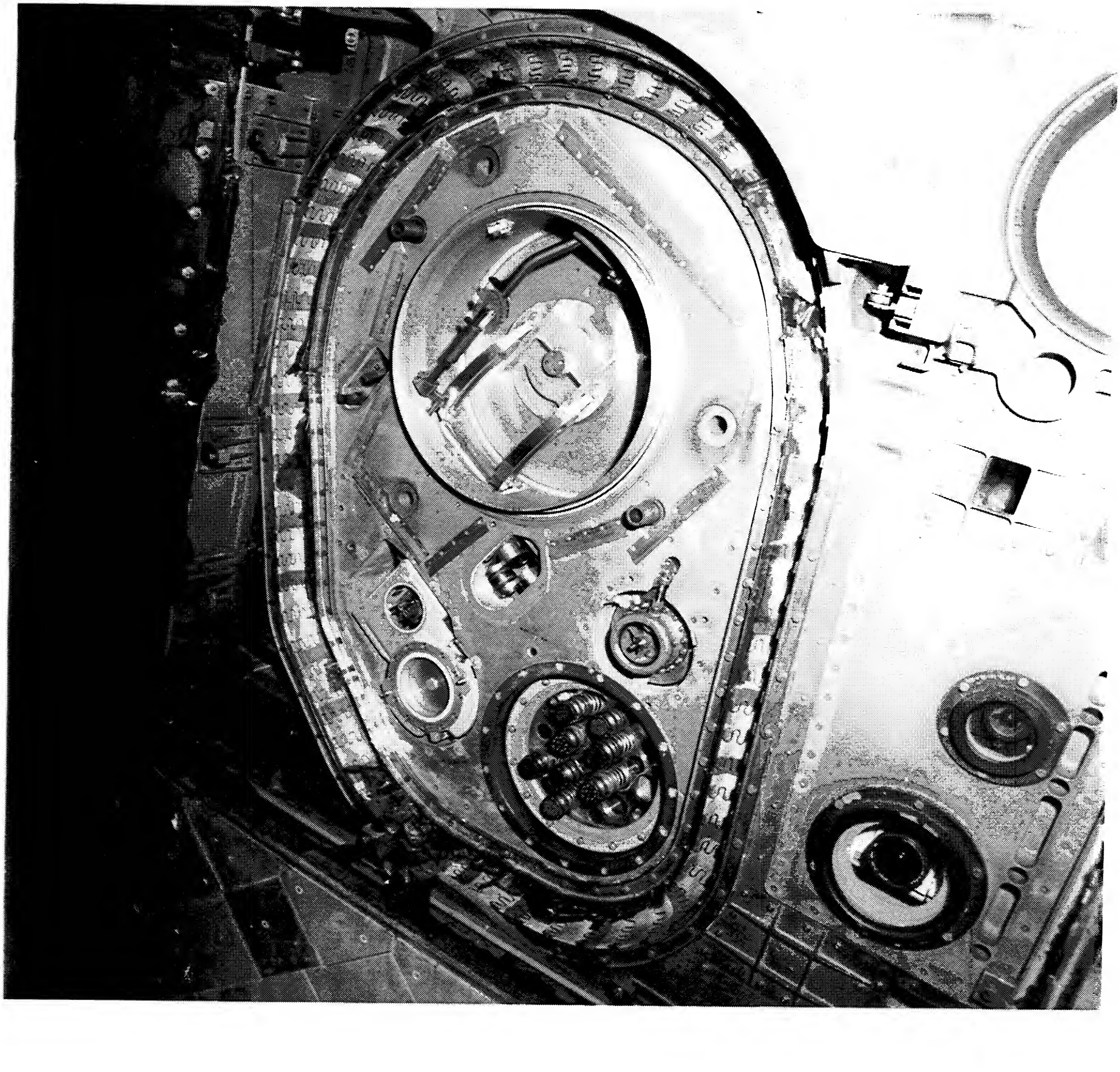


Overall view of SSME's and base heat shield. Note thermal blanket damage below SSME #1.

Close-in view of thermal (beta) blanket damage at 6 o'clock position on SSME #1



Pieces of closeout baggie material still adhere to the
LO2 ET/ORB umbilical



Overall view of LH2 ET/ORB umbilical. Two 16mm cameras with 5mm and 10mm wide angle lenses are located right of the umbilical.

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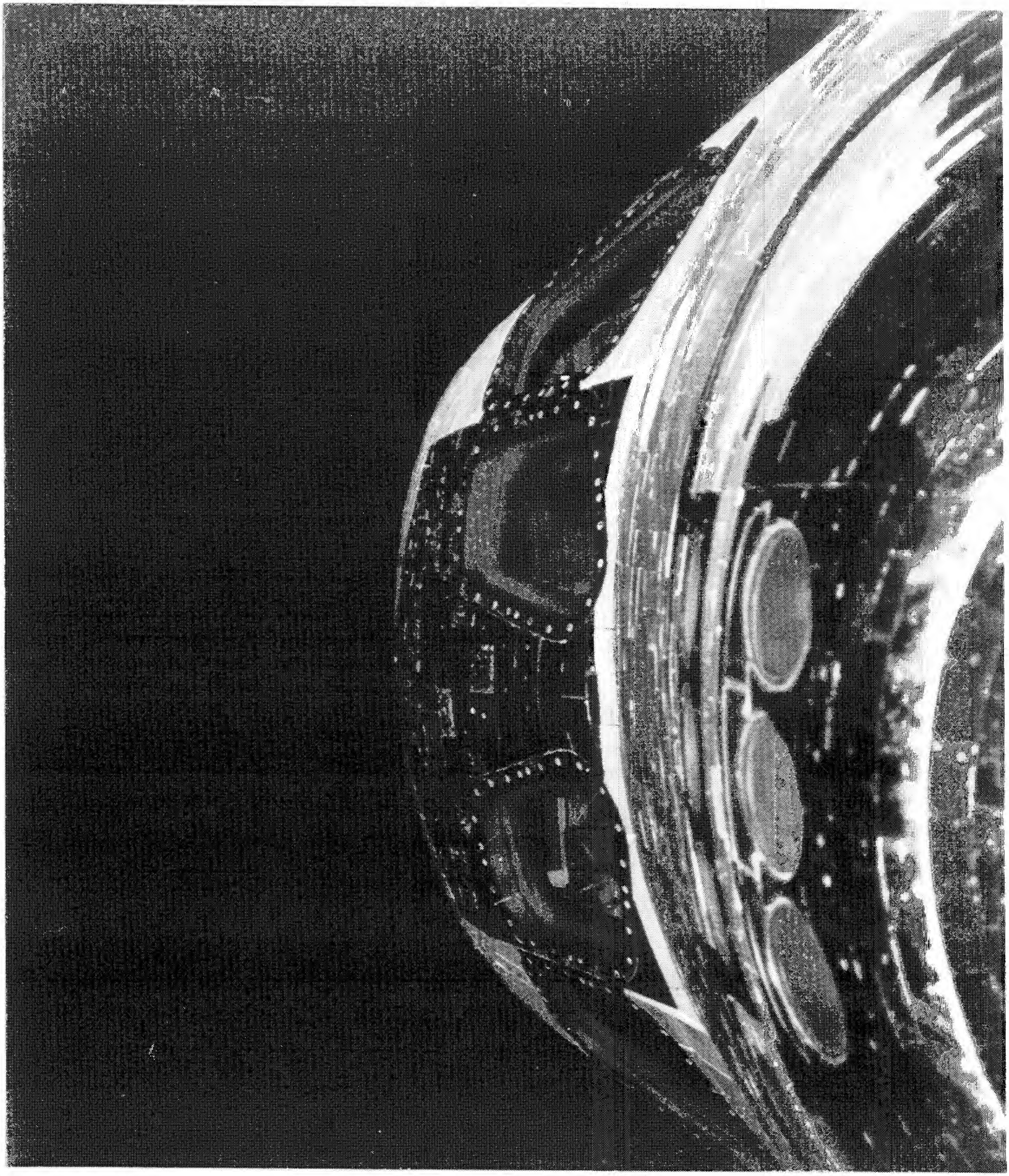
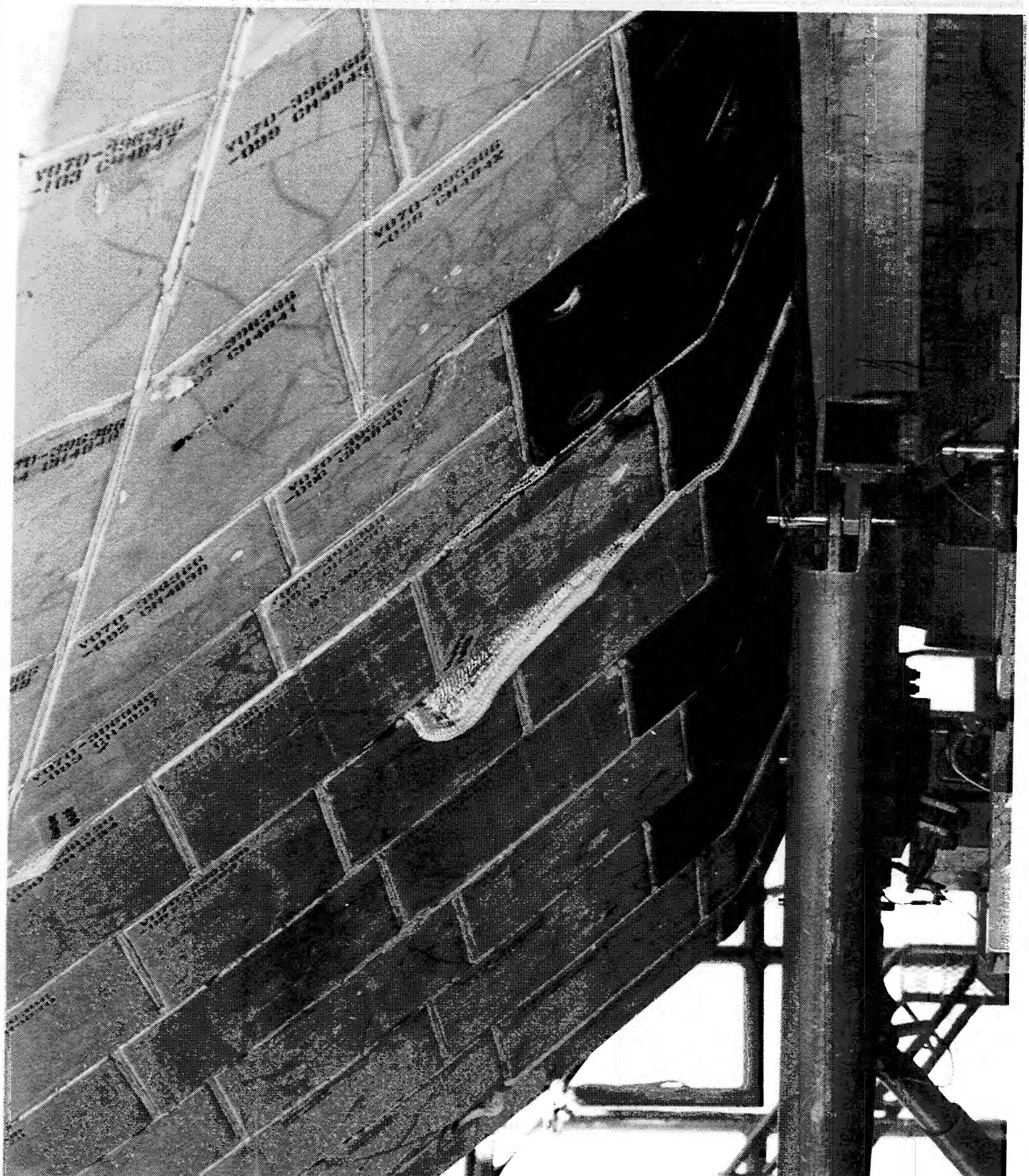
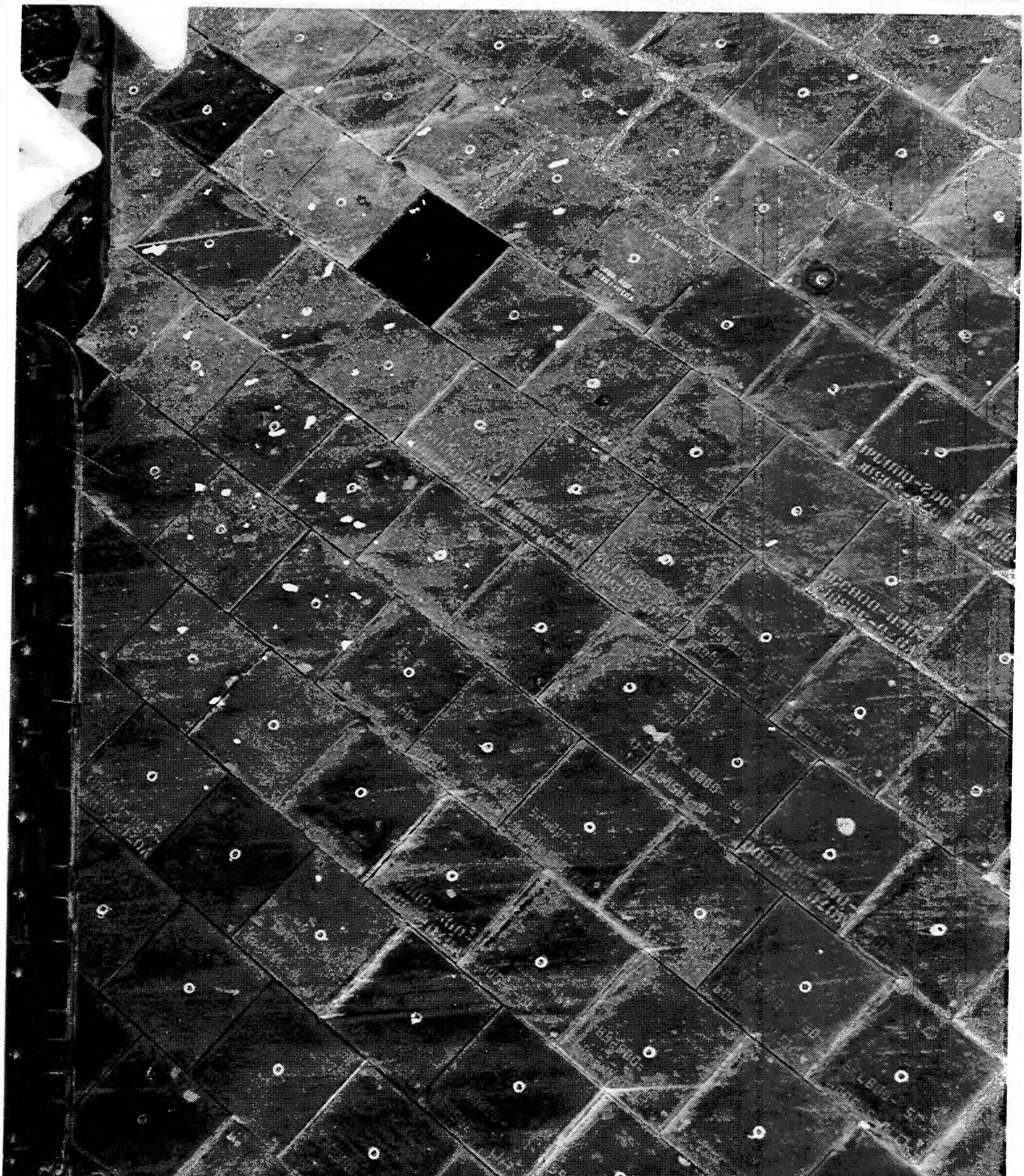


Hazing is visible on the forward facing windows #3 and #4

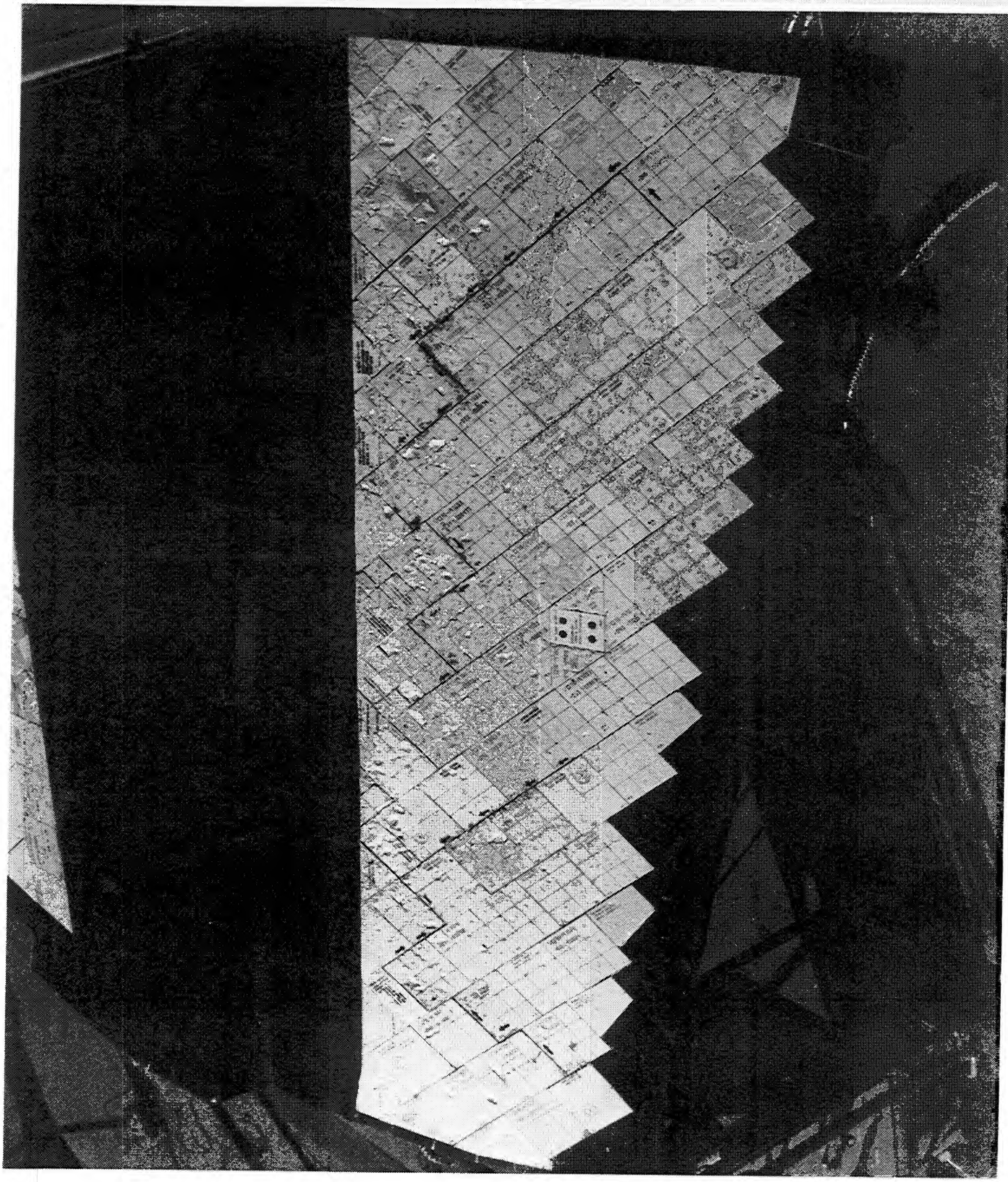


Gap filler protrudes from the LH OMS pod tiles. No damage to adjacent tiles surface coating material occurred.

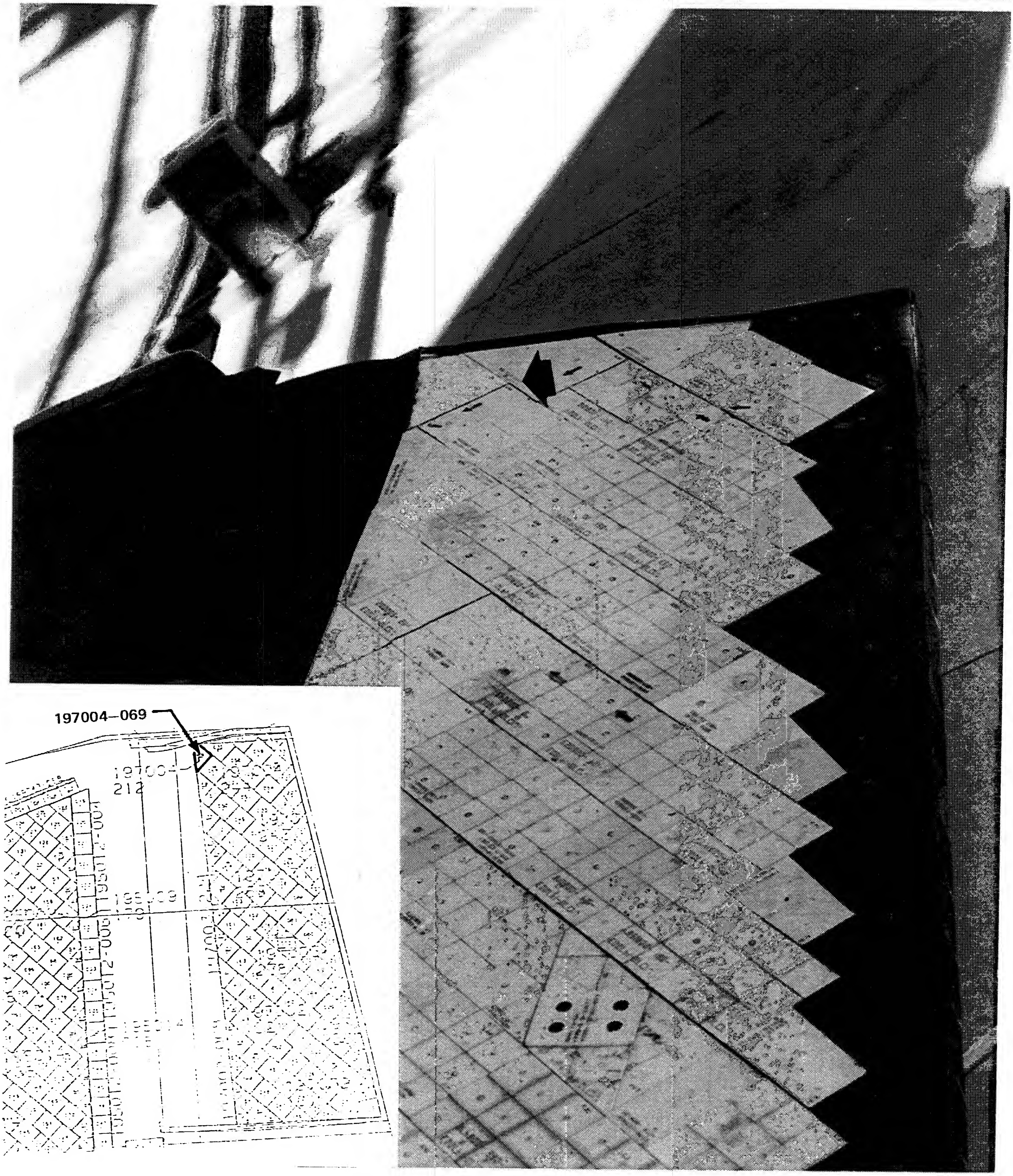


Cluster of lower surface tile damage aft of the LH2 ET/ORB umbilical is typically caused by ice impacts

Typical impact-type damage to tile surface. Note numerous repairs to small areas in surrounding tiles.



LH outboard elevon upper surface tiles have lost material, which is visible in launch films falling during SSME ignition



White tile screed repair missing from RH outboard elevon was visible in launch films falling from the vehicle

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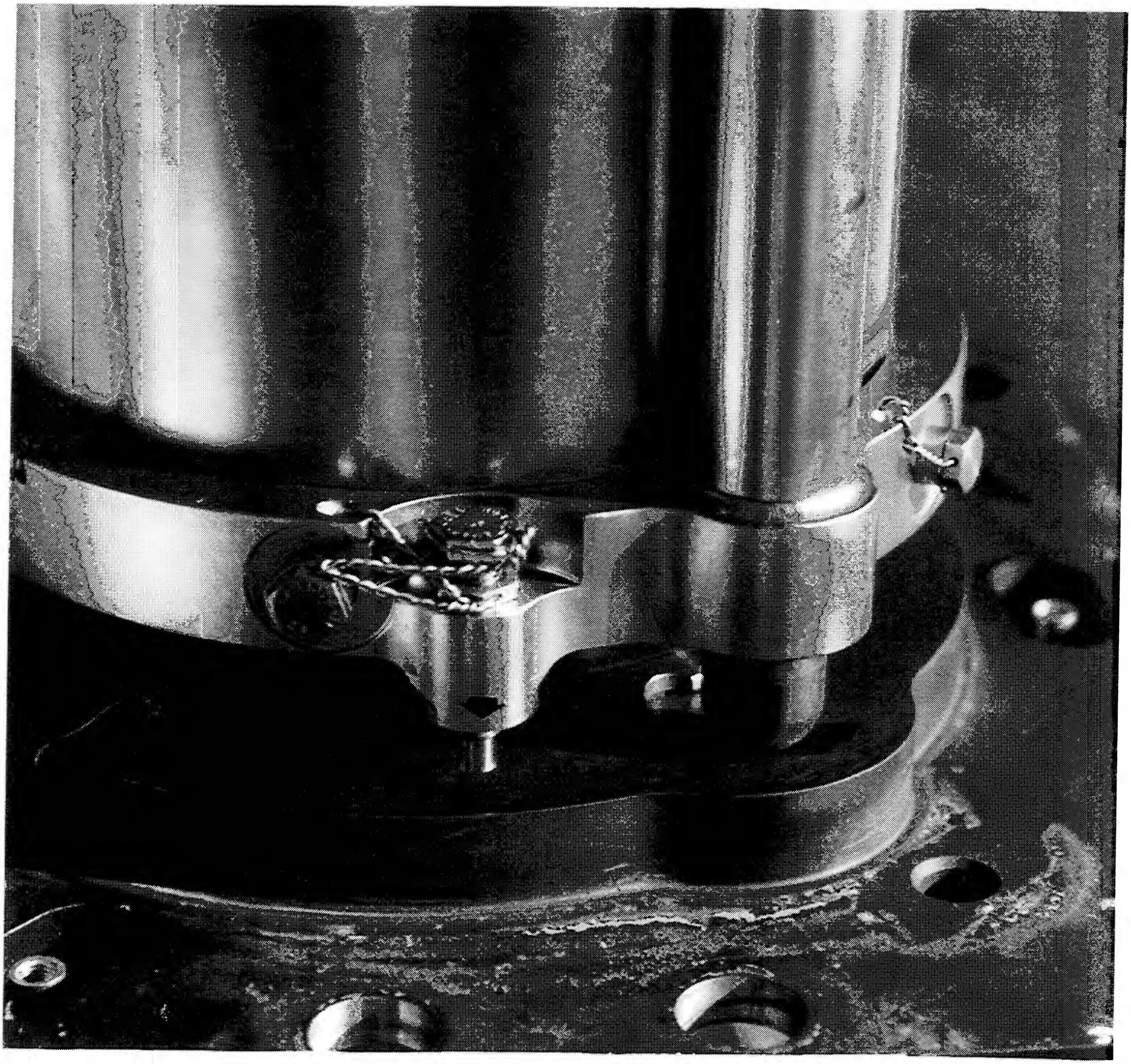

Post flight examination of EO-1 attach point revealed compressive loading damage to RH Y-Y centering bolt

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10.0 DEBRIS SAMPLE LAB REPORTS

A total of 13 samples were obtained from Orbiter OV-102 during the STS-32R post-landing debris assessment at Ames-Dryden Flight Research Facility, California. The 13 submitted samples consisted of 8 orbiter window wipes, 1 tile sample, and 4 samples from the ET/ORB umbilical area. The samples were analyzed by the NASA KSC Microchemical Analysis Branch (MAB) for material composition and comparison to known STS materials. The specific elemental analysis is shown in the appended MAB reports. Debris samples and analyses are provided by Orbiter location in the following summaries.

Orbiter Windows

Results of window wipe chemical analysis indicates the presence of the following materials:

1. Aluminum and copper metal
2. Rust, dust and salt
3. Paint
4. Muscovite
5. Tile and insulation
6. Organics

Debris analysis provides the following correlations:

1. Aluminum and copper metals are common to the landing site and are not a debris concern in this quantity (micrometer).
2. Rust is probably an SRB BSM residue; dust and salt are landing site products.
3. Paint is used as flight element and facility/ground support equipment coating.
4. Muscovite is a naturally-occurring landing site product.
5. Tile and insulation are from Orbiter thermal protection system (TPS).
6. Organic materials are probably insect/animal remains and deposits, or tile waterproofing.

ORBITER TILE

One tile damage site was sampled and the chemical analysis revealed the presence of the following materials:

1. Aluminum
2. Carbon (synthetic fibers/bundle)
3. Titanium
4. Silica tile fibers
5. Iron traces

Debris analysis provides the following correlations:

1. Aluminum is probably from SRB/BSM residue
2. Carbon appears to be the charred remains of whatever impacted the tile, and contained trace silicon, sulphur, chromium, and chlorine.
3. Titanium could be the residue of one of the elements' coatings -- ET-FRL paint or DeSoto primer; ORB-tile ink; SRB-Hypalon, Sikkens topcoat epoxy, Rustoleum topcoat.
4. Silica tile fibers are probably from Orbiter thermal protection system.
5. Iron traces are probably RTV residue or ET FRL paint residue.

ORBITER WING RCC PANELS

None of the RCC sample locations were able to provide sufficient material for analysis. The white streak material could not be removed from the RCC panels 17 & 18 and the splice panel between 10 & 11.

ET-ORBITER UMBILICAL (LH-LH2)

Chemical analysis of samples from the LH ET/ORBITER umbilical (LH2) revealed the following materials:

1. Aluminum particles
2. Rust and dust
3. Calcite
4. Black tile and insulation glass
5. Alpha-quartz
6. RTV
7. Urethane foam
8. Microballoon
9. Organics

Debris analysis provides the following correlations:

1. Aluminum particles are probably SRB/BSM exhaust residue.
2. Rust is probably of SRB BSM residue origin, dust is of naturally-occurring environmental origin.
3. Calcite is a natural landing site product.
4. Black tile and insulation glass are of Orbiter thermal protection system origin.
5. Alpha-quartz is one of the purest forms of the earth mineral silica and tile base component.
6. RTV is used as a bond/sealant on the flight elements.
7. Urethane foam is a closeout material for the umbilical.
8. Microballoon is a component of ET/SRB ablators.
9. Organics may be animal or insect remains and deposits or tile waterproofing.

ET-ORBITER UMBILICAL (RH-LOX)

Chemical analysis of samples from the RH ET/ORBITER umbilical (LOX) revealed the following materials:

1. Rust and dust
2. Calcite
3. Urethane foam
4. Microballoon
5. Organics

Debris analysis provides the following correlations:

1. Rust is probably of SRB BSM residue origin, dust is of naturally-occurring environmental origin.
2. Calcite is a natural landing site product.
3. Urethane foam is a closeout material for the umbilical.
4. Microballoon is a component of ET/SRB ablators.
5. Organics may be animal or insect remains and deposits or tile waterproofing.

Conclusions

The STS-32R mission, as evidenced by the debris analysis report, was successful in minimizing damage from debris. This is also shown to be true by the chemical analysis that was performed on post-flight samples.

The Orbiter window sampling provided results that indicated exposure to SRB BSM residue, paint, thermal protection system materials, and landing site products.

The Orbiter tile sample indicated only tile thermal protection system material and a charred synthetic fibrous carbon bundle at the damage site.

The Orbiter wing RCC panels provided no sample.

The ET/Orbiter umbilical area continues to entrap a variety of debris particles. However, none for this mission demonstrate a debris concern.

This mission provided no evidence of orbital debris impacts. The tile impact sample debris was found to be a charred synthetic fibrous material of unknown origin.

MICROCHEMICAL ANALYSIS BRANCH
DM-MSL-1, ROOM 1274, O&C BUILDING
NASA/KSC
FEBRUARY 1, 1990

<u>SUBJECT:</u> Window Wipes and Debris from STS-32R, OV-102

<u>LABORATORY REQUEST NO:</u> MCB 0043-90

<u>RELATED DOCUMENTATION:</u> Intercenter Debris Team Requirements

1.0 <u>FOREWORD:</u>

1.1 <u>REQUESTER:</u> R.F. Speece/NASA/TV-MSD-22/7-0806

1.2 <u>REQUESTER'S SAMPLE DESCRIPTION:</u> The particles were removed from OV-102, STS-32R, DFRF, California, and were identified as follows:

<u>Windows</u>
#1. Window #1, 55022, SEQ 06-005
#2. Window #2, 55022, SEQ 06-005
#3. Window #3, 55022, SEQ 06-005
#4. Window #4, 55022, SEQ 06-005
#5. Window #5, 55022, SEQ 06-005
#6. Window #6, 55022, SEQ 06-005
#7. Window #7, 55022, SEQ 06-005
#8. Window #8, 55022, SEQ 06-005

<u>Tape</u>
#9. OV-102, L/H ET Door 1/22/90
#10. OV-102, R/H ET Door 1/22/90

<u>Umbilical Cavities</u>
#11. Left Hand Umbilical
#12. Right Hand Umbilical

1.3 <u>REQUESTED:</u> Perform chemical/material identification and compare results to known STS materials.

2.0 <u>CHEMICAL ANALYSIS AND RESULTS:</u>

2.1 Procedures:

The samples were analyzed by means of optical microscopy (OM), infrared spectrometry (IRS), and electron microprobe with energy dispersive spectrometry (EDS).

2.2 Results:

2.2.1 The particulates were classified into components on the basis of color and texture by OM. The classified components from all samples are listed in Table 1 with the possible identification of each component and elemental analysis.

Table 1

Component ID	Possible Ident.	Elemental Analysis by EDS*	
		Major	Minor
1. Metallics	Cu,Al	Cu,Al	
2. Black Mtls	Rust,Dust,Salt	Fe,Si,Al,Ca,S,K	P,Cl,Mg
3. Wht-Grey Mtls	Si-Al Rich	Si,Al	Na,Cl,K
4. White Powder	Calcite	Ca	
5. Black Dense	Tile	Si	
6. Black Sphere	C-Steel Sphere	Fe	
7. White Clear	Alpha-Quartz	Si	
8. LgtBrn Flake	Muscovite	Fe,K,Si,Al	Mn,Ti,Mg
9. Glass Fiber	InsulationGlass	Ca,Si,Al	
10. Yellow Mtls	Paints	Si,Ti,Cr,S	Fe,K,S
11. Red Mtls	RTV	Fe,Si	

2.2.2 Table 2 lists estimated amounts of each component versus sample number.

Table 2

Sample No. Amt. Sample	#1	#2	#3	#4	#5	#6	#7	#8	#9	#10	#11	#12
1.Metallics	2(Cu)	X	T(Cu Al)	X	T(Cu)	X	T(Cu)	X	1(Al)	X	X	X
2.Dust or Rust	15	10	10	1	2	4	4	10	5	30	X	X
3.Si-Al or Salt	71	80	89	99	98	10	96	90	X	X	X	X
4.Calcite	X	X	X	X	X	X	X	X	20	60	X	X
5.Tile	X	X	X	X	X	X	X	X	1	X	X	X
6.C-SteelSphere	X	X	X	X	X	X	X	X	1	X	X	X
7.Alpha-Quartz	X	X	X	X	X	X	X	X	2	X	X	X
8.Muscovite	10	8	X	X	T	X	T	T	X	X	X	X
9.Tile or Insulation	T	T	X	T	X	X	T	X	30	X	X	X
10.Paints, Primer	X	T	X	X	X	X	X	X	X	X	X	X
11.RTV	X	X	X	X	X	X	X	X	T	X	X	X
12.Foam	X	X	X	X	X	X	X	X	30	10	100	100
13.Microballoon	X	X	X	X	X	X	X	X	T	T	X	X
14.Organics	2	2	1	T	T	86	T	T	8	T	X	X
Particle Size Size, um	1-80	1-150	1-80	1-20	1-30	1-70	1-150	1-50	1-500	1-300	---	---

X: Not detected.
T: Trace
(Al) and (Cu): Al-, Cu-Metals

2.2.3 Figures 1, 2, 3, and 4 are EDS spectra of light-brown flakes, white materials, black materials in sample #6, and black materials in sample #8, respectively.

3.0 CONCLUSIONS:

3.1 WINDOWS (SAMPLE #1 THROUGH #8)

3.1.1 The sample numbers 1, 3, 5, 7, and 9 contained trace amounts of metallics. The metallics were composed of Cu- and Al-metals.

3.1.2 All samples contained black-colored rust and dust. All samples contained large amounts of Si-Al rich high temperature materials. These materials might be formed from the thermal tile upon reentry.

3.1.3 The sample numbers 1, 2, 5, 7, and 8 contained muscovite [KAl2(AlSi3O10)(OH)2].

3.1.4 The sample numbers 1, 2, 4, and 7 contained trace amounts of either insulation glass or tile glass fibers.

3.1.5 The sample number 2 contained trace amounts of paints.

3.1.6 All samples contained organics. the organics were not analyzed due to small amounts of samples.

3.2 <u>TAPES (SAMPLE #9 AND #10)</u>

3.2.1 The sample #9 contained Al-particles, dust, rust, calcite, black tiles, C-steel spheres, Alpha-Quartz (Alpha-SiO_2), insulation glass fiber, RTV, urethane foam, microballoon and organics.

3.2.2 The sample #10 was composed of dust, rust, calcite, urethane foam, microballoon and organics.

3.3 <u>UMBILICAL CAVITIES</u>

3.3.1 Both sample numbers 11 and 12 were composed entirely of urethane foam.

3.4 The Si-Al rich amorphous materials, tile and insulation glass fibers appeared to be originated from TPS and the rest of materials appeared to be originated from the natural environment.

3.5 The particle sizes were estimated to be in the range of 1 to 500 micrometers.

CHEMIST: H. S. Kim
H. S. Kim

APPROVED: J. F. Jones
J. F. Jones

Figure 1. LGT BRN FLAKES,0043-90

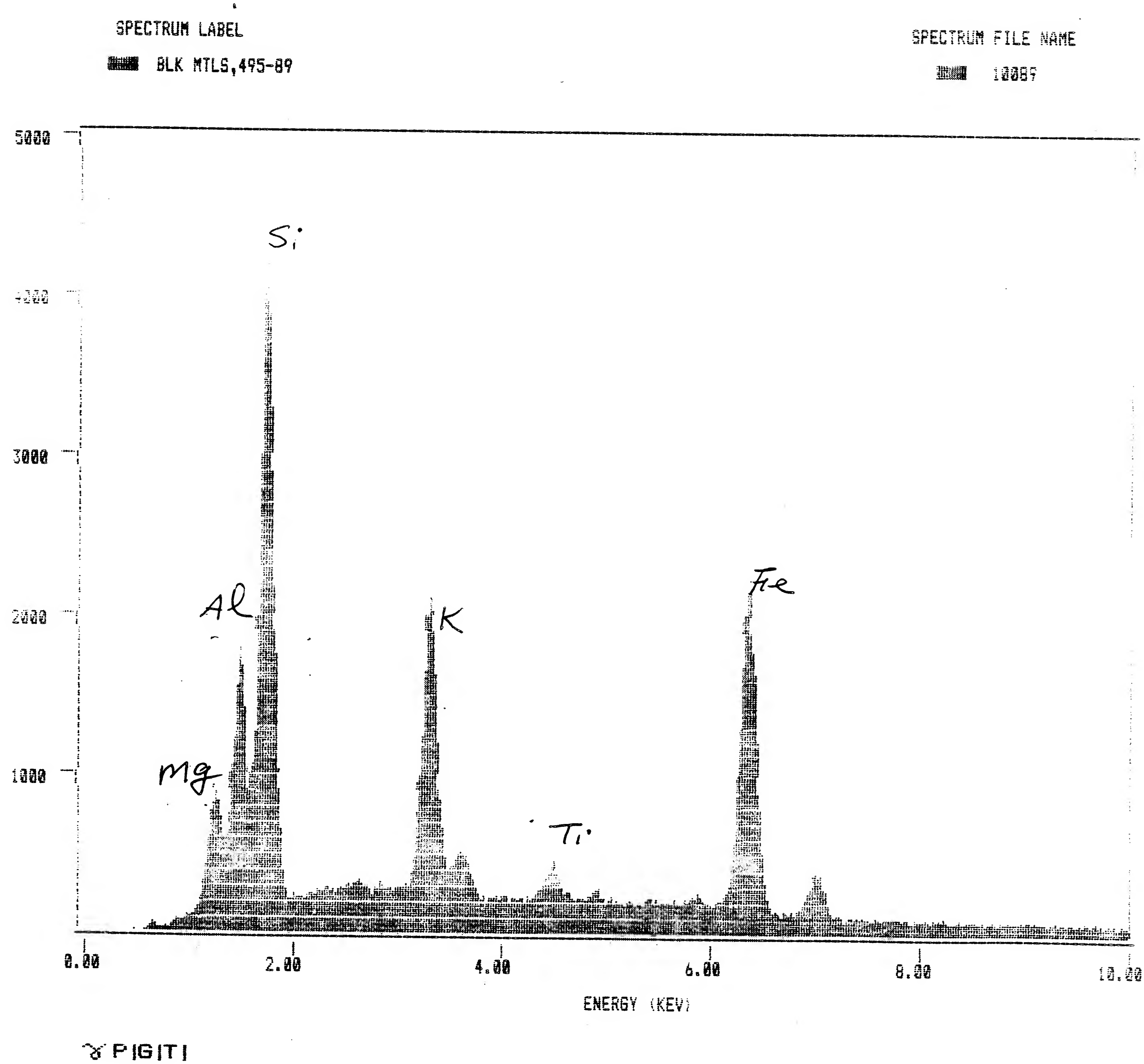

Figure 2.

WHITE MTLS,4,0043-90

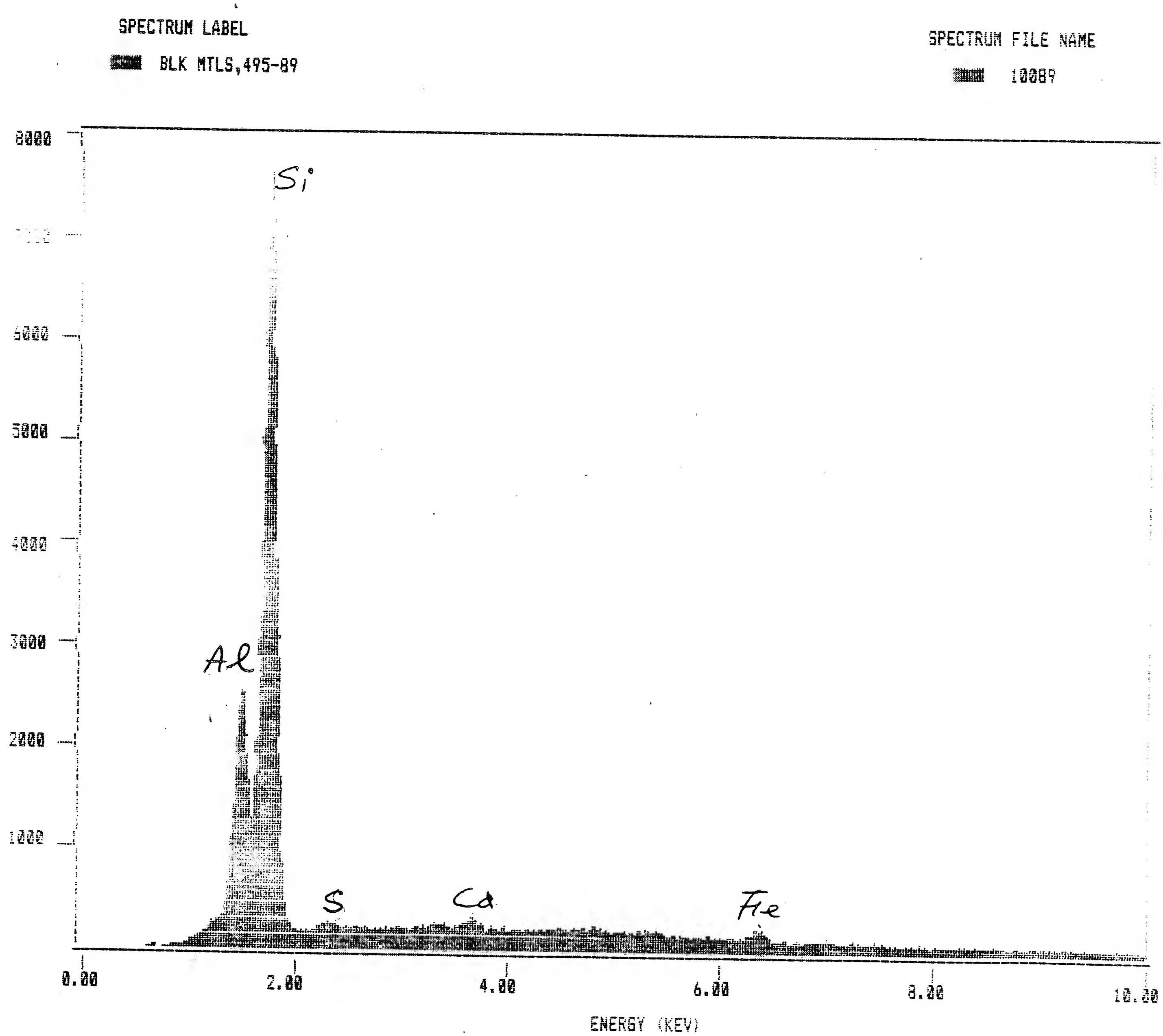

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Figure 3. BLK MTLS,6,0043-89

SPECTRUM LABEL

BLK MTLS,495-89

SPECTRUM FILE NAME

10089

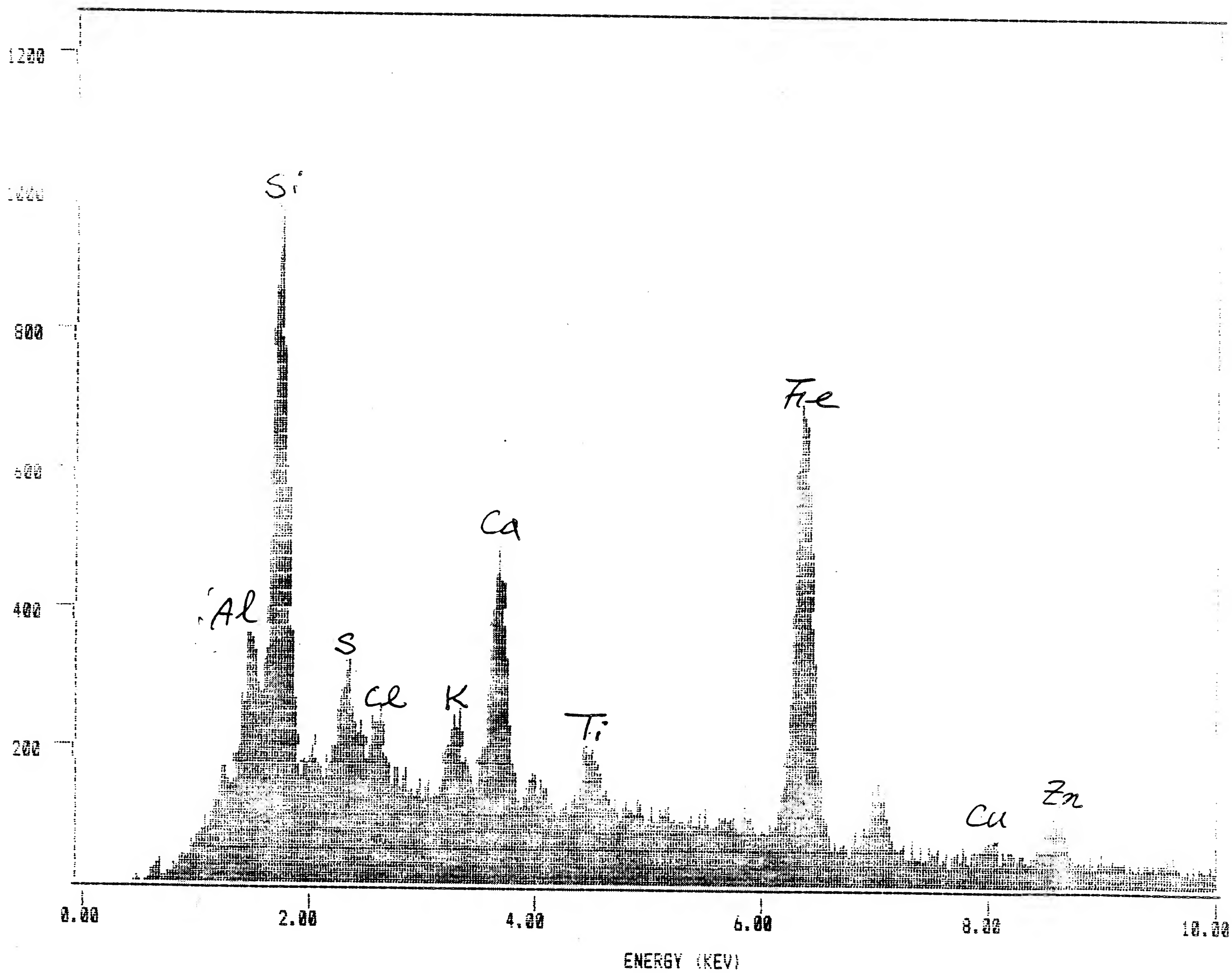

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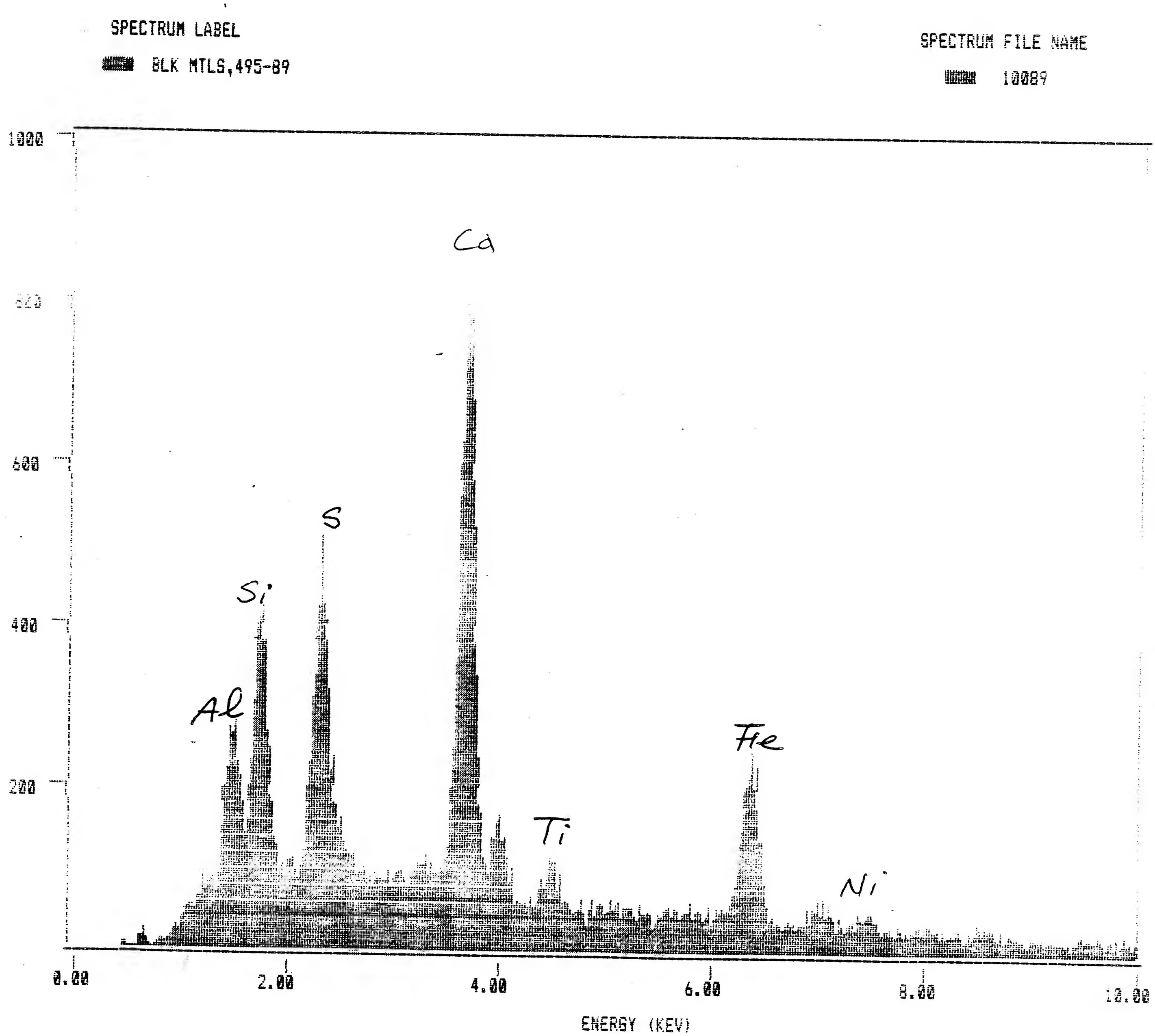
Figure 4.

BLK MTLS,8,0043-89



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MICROCHEMICAL ANALYSIS BRANCH
DM-MSL-1, ROOM 1274, O&C BUILDING
NASA/KSC
February 7, 1990

SUBJECT: Sample from Tile Damage Site OV-102, STS-32R

LABORATORY REQUEST NO: MCB-0053-90

RELATED DOCUMENTATION: Intercenter Debris Team Requirements

1.0 **FOREWORD:**

1.1 **REQUESTER:** R.F. Speece/TV-MSD-22/7-0806

1.2 **REQUESTER'S SAMPLE DESCRIPTION:**

Sample from tile damage site, tile VO70-394503-169 Orbiter lower surface, STS-32R, OV-102, DFRF, Calif.

1.3 **REQUESTED:**

Perform chemical/material identification analysis; compare results to known STS materials.

2.0 **CHEMICAL ANALYSIS AND RESULTS:**

2.1 Particulates were was examined by scanning electron microscope (SEM) and analyzed by X-ray energy dispersive spectroscopy (EDS). EDS analysis provides a qualitative and semiquantitative analysis of all elements in the periodic table above boron (5). The method is sensitive to most elements if they are present above 0.4% by weight. Light elements (below #9 in the periodic table) have less sensitivity and require higher relative weight percentages for detection.

2.2 Individual particles from the sample that were analyzed by EDS are shown in optical photo 1, and larger parts that are obviously black (and white) fragments of the tile surface are shown in optical photo 2.

2.3 EDS analyses of the particles shown in photo 1 indicated that the black and the glassy white particulates were nearly pure silica (only silicon and oxygen peaks). However analyses of 12 of the white particles shown in photo 1 indicated varying levels of aluminium, carbon and titanium in addition to the silicon and oxygen of the silica tile fibers. Some of these analyses are provided with this report as figures 1 through 3. A

slight trace of iron was shown in figure 3, but this may be due to iron in the red RTV material (two RTV particles were analyzed) that is often found with the tile residue. The only other particles found included some synthetic fibers and a fiber bundle that appears in polarized light to be carbon. The EDS analysis of this fiber bundle is presented in figure 4. In addition to the carbon it contains traces of silicon, sulfur, chromium and chlorine.

2.4 EDS analysis of the black sides and white sides of the tile surface particles shown in photo 2 indicated only silica (silicon and oxygen peaks).

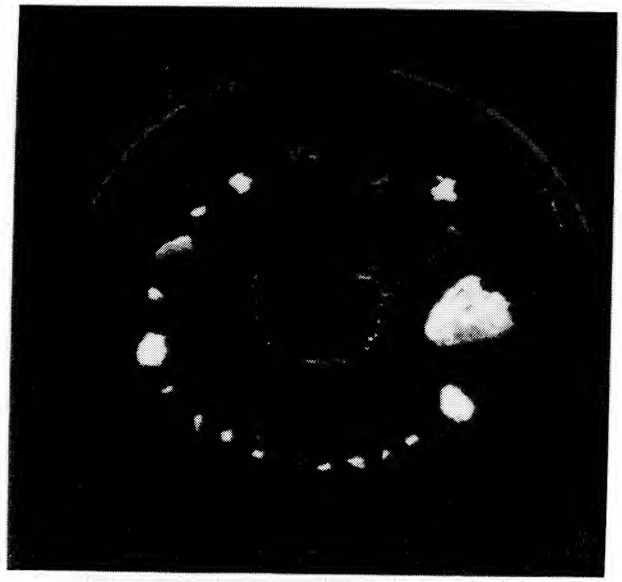
3.0 CONCLUSIONS:

Several particles of this sample contained varying levels of aluminum, titanium and carbon in addition to the silicon and oxygen of the glass fiber tile material. These may be charred residues of whatever impacted the tile.

CHEMIST: Stan Young
Stan Young

APPROVED: J. F. Jones
J. F. Jones

1



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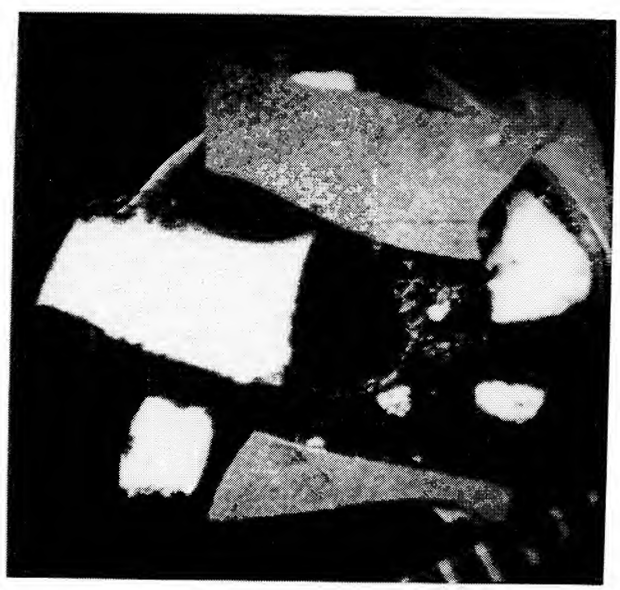

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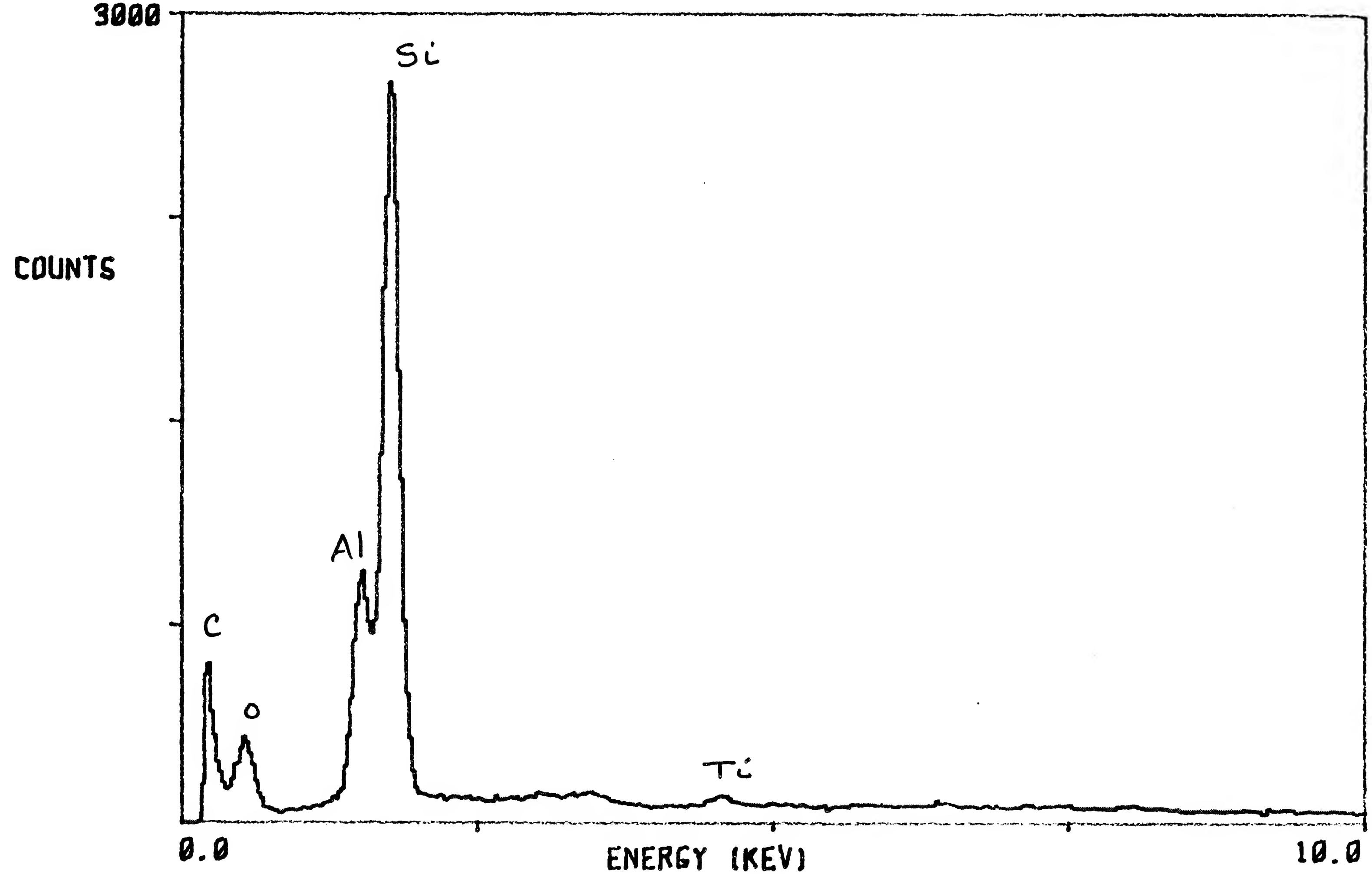
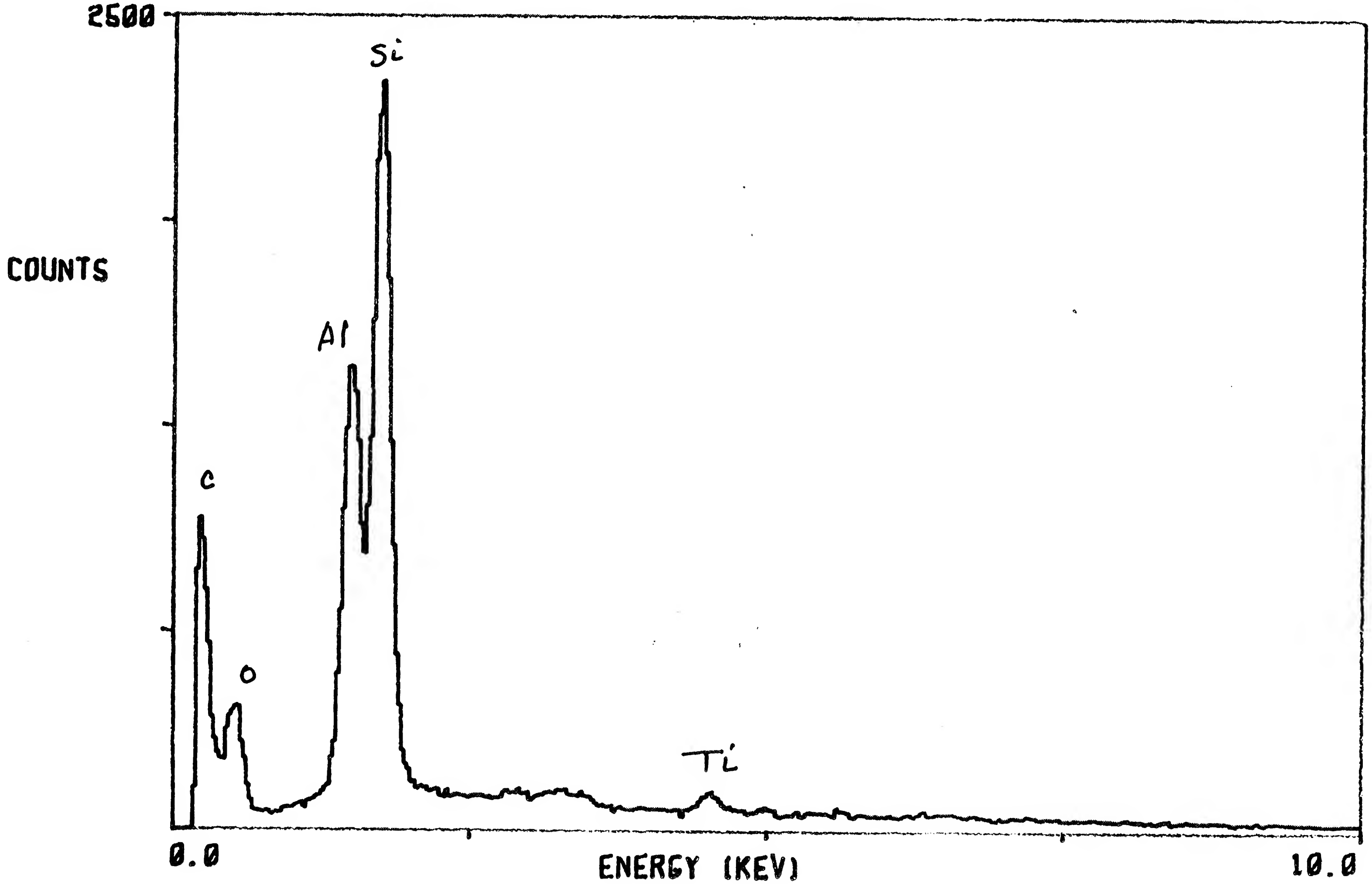
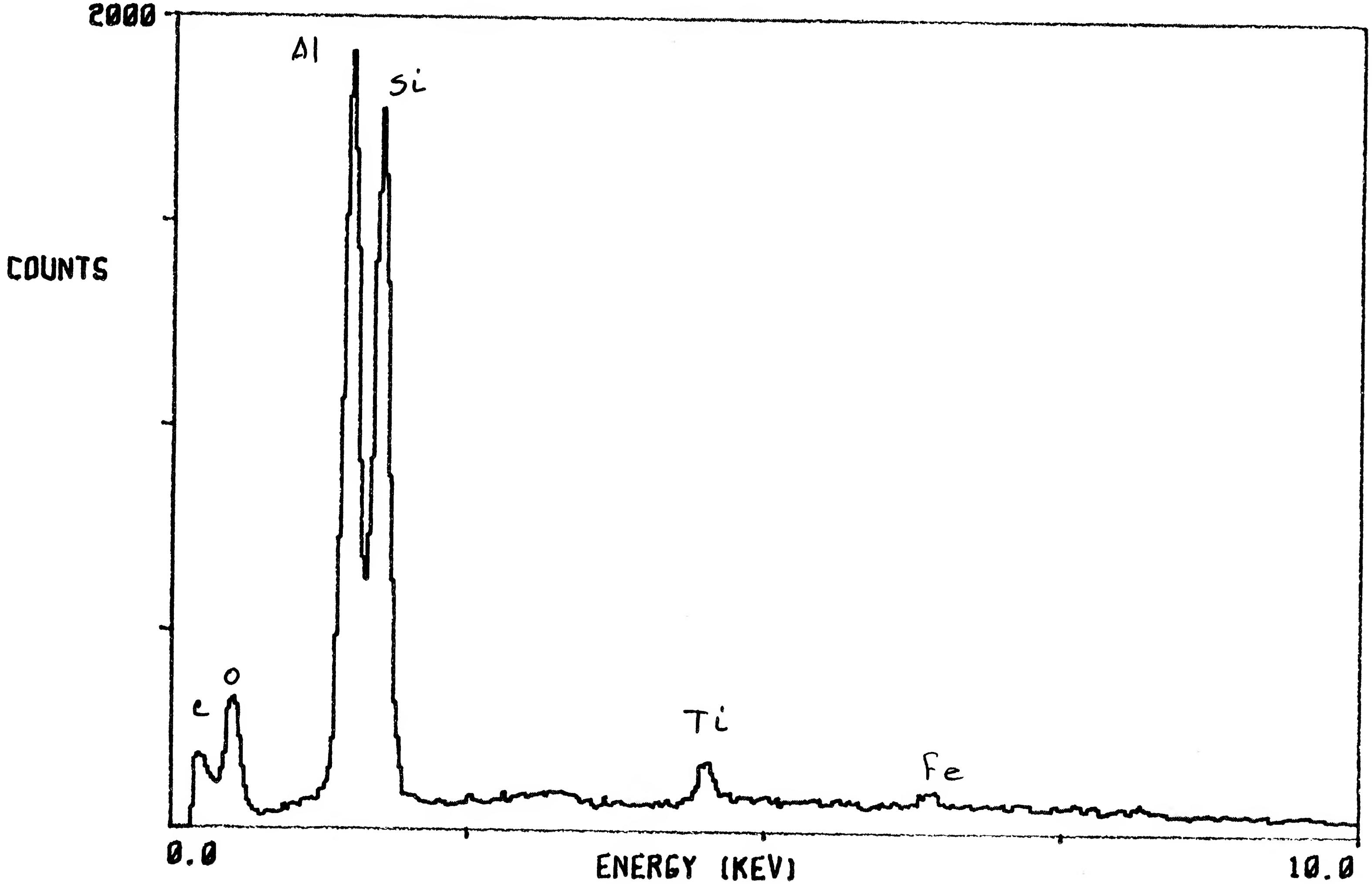
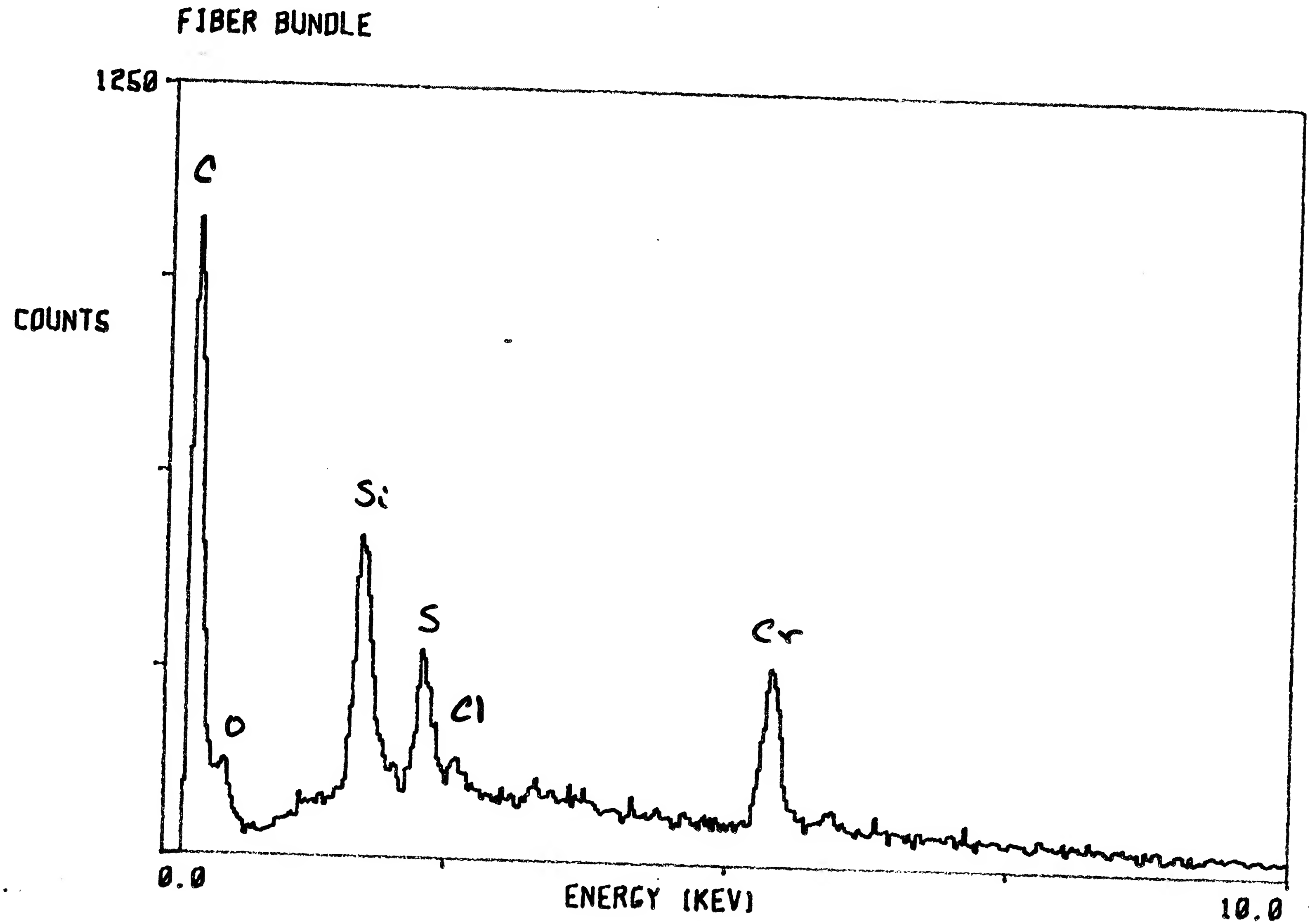


(2)




2000
COUNTS
Al
Si
C
O
Ti
Fe
0.0
ENERGY (KEV)
10.0



FIBER BUNDLE
1250
COUNTS
C
O
Si
S
Cl
Cr
0.0
ENERGY (KEV)
10.0

11.0 POST LAUNCH ANOMALIES

Based on the debris inspections and film review, 20 Post Launch Anomalies were observed for STS-32R.

11.1 POST LAUNCH PAD INSPECTION

1. Three Q-felt closeout plugs from the Orbiter base heatshield were found on the pad after launch.

2. Two pieces of holddown post shoe shim material were found. (Reference Film, item 5; SRB, item 8)

3. A piece of tile 4"x3-3/8"x1/2" maximum thickness was found on Pad A approximately 700 feet west of the FSS. The tile piece was determined to be mostly an unrestricted 364 screed repair from tile 197004-069. This tile is located on the RH elevon upper surface at the forward outboard corner. (Reference Film, item 4)

4. Inspection of the SRB holddown post sandboxes revealed the following debris (Reference Film, item 1; SRB, item 7):

HDP #1	1 metal fragment
HDP #2	2 frangible nut webs
HDP #3	1 NSI cartridge, 1 metal fragment
HDP #4	6 small (less than 1/2") fragments, one of which is a piece of frangible nut web
HDP #5	1 frangible nut web, 1 piece of NSI cartridge with threads, 1 nut fragment, 1 metal fragment
HDP #6	1 metal fragment
HDP #7	None
HDP #8	1 NSI cartridge fragment with threads, 5 small metal fragments

11.2 FILM REVIEW

1. A small object, possibly an NSI cartridge fragment, fell from the RH SRB HDP #3 stud hole just before the aft skirt foot cleared the holddown post doghouse blast cover. Thirteen pieces of frangible nut and/or NSI cartridge fragments fell from the LH SRB aft skirt HDP #5 stud hole shortly after liftoff. One object fell from the LH SRB HDP #7 stud hole shortly after liftoff. Two objects, most likely frangible nut/NSI fragments, fell from the LH SRB HDP #8 aft skirt stud hole as the vehicle ascended. (Reference Pad, item 4; SRB, item 7)

2. A few small pieces of tile surface coating material from tiles on the base heatshield and aft faces of the RCS stingers were shaken loose by SSME ignition acoustics.

3. An orange GSE tile shim fell between the RH elevons. This may be the tile shim identified during the Ice Inspection protruding from the lower surface tiles near RCC panel #14.

4. A white object appears to originate from the Orbiter RH wing tip area near the end of the roll maneuver. The object is most likely the white tile fragment. (Reference Pad, item 3)

5. A piece of Epon shim was debonded from the shoe of HDP #2 and pulled upward by the SRB aft skirt foot. As the vehicle continued to rise, this piece fell back into the shoe. (Reference Pad, item 2; SRB, item 8)

11.3 SRB POST FLIGHT/RETRIEVAL INSPECTION

1. The RH frustum was missing no TPS but exhibited 5 debonds over bolt heads and one 1.75-inch diameter acreage debond. The LH frustum exhibited 23 debonds and one 2-inch divot near the 275 ring.

2. The +Z RSS antenna phenolic plate on both RH and LH forward skirt was delaminated/missing.

3. The RH forward field joint had a 1.5-inch diameter delamination within the cork material at the 190 degree radial location 2.5 inches aft of the forward edge.

4. A bolt head on one of the RH SRB IEA covers was missing.

5. Two K5NA thermal protective domes were missing from bolt heads on the aft side of the RH SRB kick ring at 260 degrees and the uncovered substrate showed signs of heating prior to water impact.

6. The LH aft segment factory joint EPDM moisture seal was debonded on the leading edge at 240 degrees (3.5" long by 1" deep) and 200 degrees (3" long by 1.25" deep).

7. Only three plungers in the Debris Containment Assemblies were seated. Several spherical washers were displaced and plungers were jammed by frangible nut/NSI cartridge debris. (Reference Pad, item 4; Film, item 1)

8. A 15"x3.5" piece of shim was missing from the inboard edge of holddown post #4 aft skirt foot prior to water impact. (Reference Pad, item 2; Film, item 5)

11.4 ORBITER POST LANDING INSPECTION

1. EO-1 mechanism had rotated forward sufficiently to contact the LH and RH bulkhead pyro connector backshells, as evidenced by scratch marks on the ordnance device spring housings. The RH Y-Y centering bolt, which had been bent on STS-34, showed signs of compressive loading.

2. The corner (1-1/2"x 1-1/2") of a tile (V070-292110-005-004) on the left side of the rudder was missing.

3. An 8"x2" section of FRSI blanket on the LH aft section of the payload bay door was loose (peeled back).

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Report Documentation Page

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15. Supplementary Notes

16. Abstract

A Debris/Ice/TPS assessment and photographic analysis was conducted for Space Shuttle Mission STS-32R. Debris inspections of the flight elements and launch pad are performed before and after launch. Ice/frost conditions on the External Tank are assessed by the use of computer programs, nomographs, and infrared scanner data during cryogenic loading of the vehicle followed by on-pad visual inspection. High speed photography is analyzed after launch to identify ice/debris sources and evaluate potential vehicle damage and/or in-flight anomalies. This report documents the debris/ice/TPS conditions and photographic analysis of Mission STS-32R, and their overall effect on the Space Shuttle program.

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